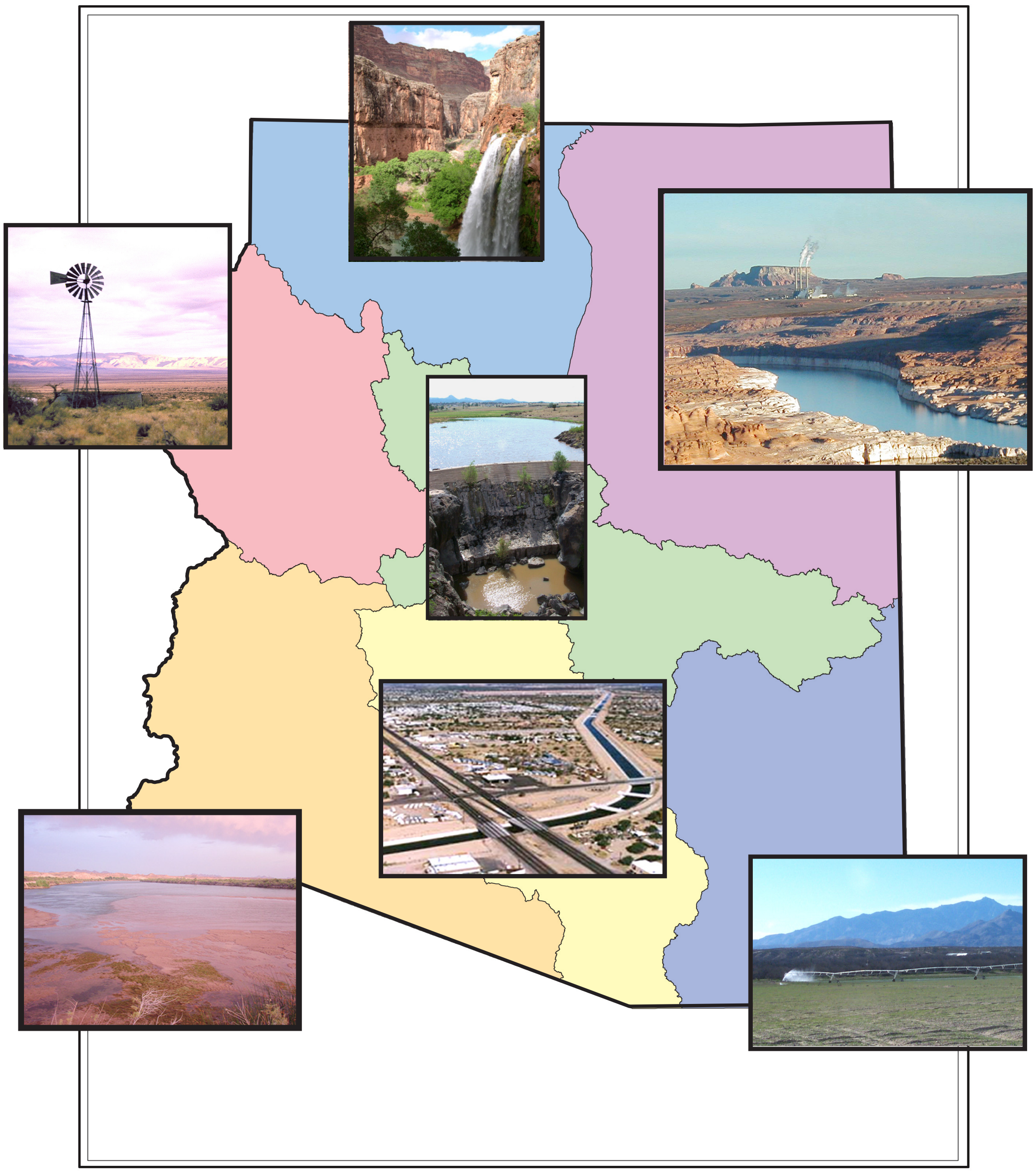
ARIZONA WATER ATLAS

VOLUME 1 INTRODUCTION



Arizona Department of Water Resources

DRAFT

JUNE 2006

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ARIZONA WATER ATLAS

VOLUME 1 INTRODUCTION

The Arizona Water Atlas (Atlas) is a compilation of currently available water-related information for the State of Arizona. Water is managed differently within the state's five active management areas (AMAs) than it is in areas outside AMAs. This difference influences the organization and to some extent, the content of the Atlas. The Atlas is composed of nine volumes. In addition to this introductory volume there are individual planning area volumes (Volumes 2-7) for each of the six planning areas outside of AMAs. These planning areas are composed of groundwater basins as shown on Figure 1-1. The AMAs are considered a separate planning area and are described in Volume 8 of the Atlas. Volume 9 is a summary volume for the entire state. The term "rural" is often used to describe the non-AMA areas of the state. Although this is somewhat of a misnomer since there are many cities and towns outside the AMAs that are large, diverse and face water supply issues similar to the AMAs, the term is widely used and appears in the Atlas.

The primary objectives of the Atlas are to present an overview of water supply and demand conditions, to provide water resource information for planning and resource development purposes and to help identify the needs of communities throughout Arizona, particularly those outside the AMAs. The emphasis on areas outside AMAs is in recognition of the more immediate need for water resource information by decision-makers and the public for local planning, water management and general information purposes in these areas. The Arizona Department of Water Resources (Department), legislative leaders and local groups have long recognized the need to support Arizona water resource planning efforts outside AMAs. Adoption of the 2004 Arizona Drought Plan and associated legislation, initiation of the Statewide Water Conservation Program, establishment of a Rural Water Legislative Study Committee (2005-2007), formation of a Statewide Water Advisory Group to focus on programs for water resources development and management outside of AMAs (2006) and recent legislative funding, provide additional resources to address Arizona's water information and planning needs.

SECTION 1.0 Atlas Purpose and Scope

The purposes of the Arizona Water Atlas are to:

1. Provide a comprehensive overview of regional water supply and demand conditions that has not been available on a statewide basis for over ten years;
2. Identify water resource issues facing Arizona communities;
3. Identify missing information and how it could be improved; and
4. Initiate a renewed and more systematic effort by the Department to assist Arizona water planning efforts and the development of solutions.

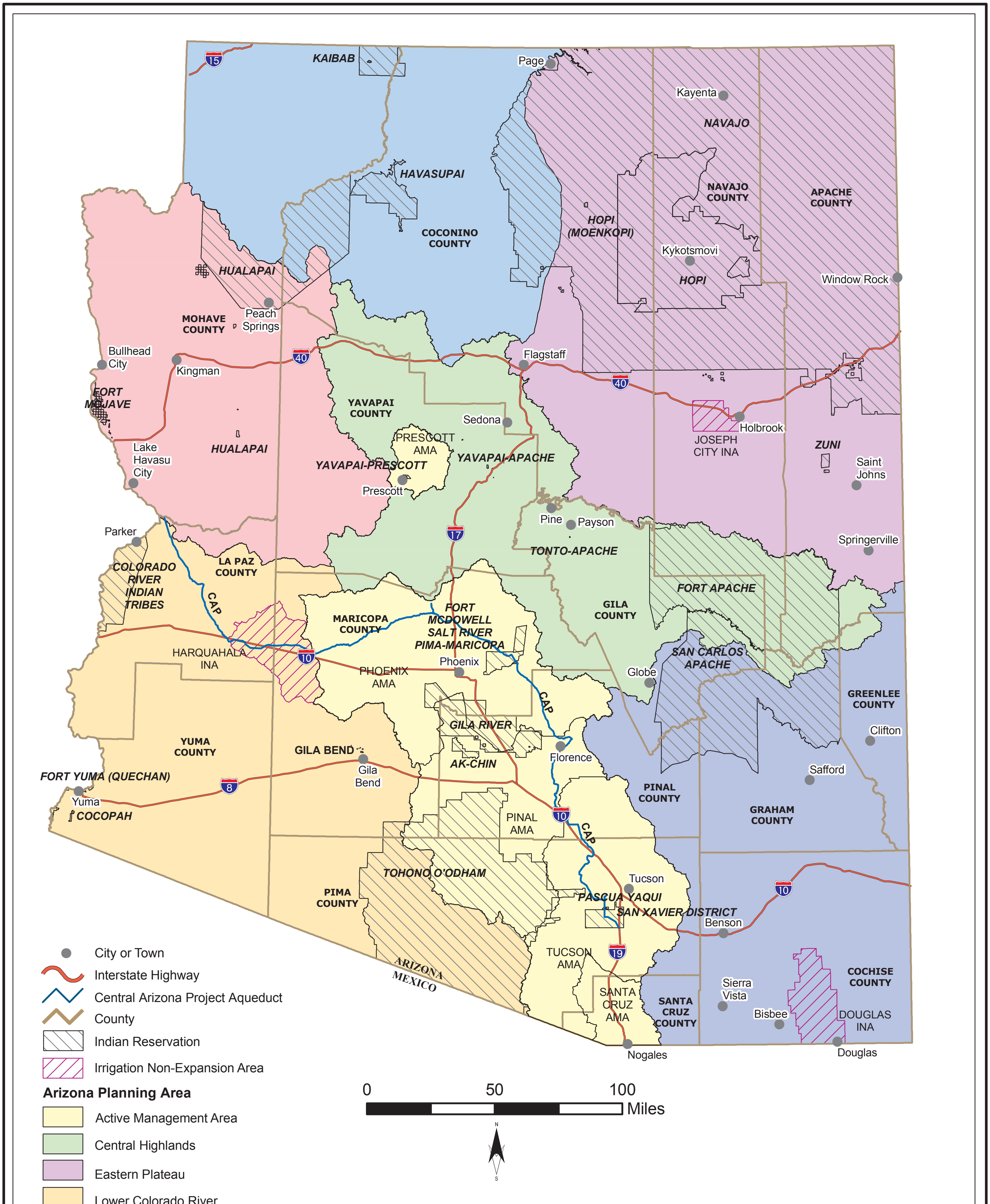


Figure 1 - 1
Arizona Planning Areas

ARIZONA DEPARTMENT OF WATER RESOURCES

The information contained in Volumes 2-8 of the Atlas has been compiled from a number of sources, discussed in Section 1.3, Data Sources and Methods, and has been reviewed and synthesized. New investigations, except as noted, were not undertaken. Because multiple data sources were utilized, the Atlas is the first comprehensive compilation and presentation of certain data. In some cases, such as certain water demand figures, information is based on estimates because measurement and reporting of water withdrawals, diversions and uses are generally not required outside AMAs.

While the Atlas includes a listing of water resource issues, proposing solutions is outside its scope. Instead, the Atlas provides some of the necessary information and identifies data necessary for development of solutions by local stakeholders.

SECTION 1.1 Atlas Organization

The Atlas is organized into nine volumes; this Introduction, six non-AMA planning area volumes, an AMA planning area volume and a summary volume. "Planning areas" are composed of groupings of groundwater basins and were utilized as an organizational theme in the 1994 *Arizona Water Resources Assessment (Assessment)*. A groundwater basin is a relatively hydrologically distinct body or related bodies of groundwater (A.R.S. § 45-402(13)). The *Assessment* and the 1975 *Inventory of Resource and Uses* prepared by the Arizona Water Commission are the only previous comprehensive studies that provide a statewide overview of Arizona's water supply, demand and related issues. The planning area concept provides for a more regional perspective on supply, demand and issues identification. Volume 1, *Introduction* is intended to be a companion report to each of the other volumes. It is anticipated that most readers would be primarily interested in a particular region, so they would need only a specific planning area volume in addition to the *Introduction.*

This volume contains a synopsis of geography and climate, a general overview of state water resources and management, a summary of water planning and water resource investigations, data sources and methods used to compile the Atlas, and Appendices. This volume contains few maps and tables compared to the planning area volumes (see Table of Contents).

Volumes 2 through 8 each contain an overview of one planning area and a separate section for each of the groundwater basins or AMAs within the planning area. Each volume generally includes the following planning area maps, tables and figures, with some variations:

Planning Area Maps, Figures and Tables

- Arizona planning areas and groundwater basins (map)
- Planning area with basins (map)
- Average temperature and precipitation in the planning area 1930-2002 (figure)
- Average monthly precipitation and temperature (figure)
- Planning area-specific climate (figure)
- Precipitation departures from average 1000-1988 (figure)
- Arizona Water Protection fund grants in the planning area (table)
- Location of instream flow applications and permits (map)
- Instream flow applications and permits (table)
- Listed threatened and endangered species in the planning area (table)
- Population (figure)
- Contamination sites (map)

- Cultural water demand (tables and figures)
- Planning area water resource issues (tables)

Each basin or AMA section in the planning area volumes contains discussion and data on basin geography, land ownership, climate, surface-water conditions, groundwater conditions, water quality, cultural water use characteristics, water resource issues and includes references and further readings. The planning area volumes and associated basins or AMAs are:

Planning Area Volumes, Basins and AMAs

Volume 2 — Eastern Plateau Planning Area (1 groundwater basin)
- Little Colorado River Plateau Groundwater Basin

Volume 3 — Southeastern Arizona Planning Area (14 groundwater basins)

Aravaipa Canyon Basin	Bonita Creek Basin
Cienega Creek Basin	Donnelly Wash Basin
Douglas Basin	Dripping Springs Wash Basin
Duncan Valley Basin	Lower San Pedro Basin
Morenci Basin	Safford Basin
San Bernardino Valley Basin	San Rafael Basin
Upper San Pedro Basin	Willcox Basin

Volume 4 — Upper Colorado River Planning Area (9 groundwater basins)

Big Sandy Basin	Bill Williams Basin
Detrital Valley Basin	Hualapai Valley Basin
Lake Havasu Basin	Lake Mohave Basin
Meadview Basin	Peach Springs Basin
Sacramento Valley Basin	

Volume 5 — Central Highlands Planning Area (5 groundwater basins)

Agua Fria Basin	Salt River Basin
Tonto Creek Basin	Upper Hassayampa Basin
Verde River Basin	

Volume 6 — Western Plateau Planning Area (6 groundwater basins)

Coconino Plateau Basin	Grand Wash Basin
Kanab Plateau Basin	Paria Basin
Shivwits Basin	Virgin River Basin

Volume 7 — Lower Colorado River Planning Area (11 groundwater basins)

Butler Valley Basin	Gila Bend Basin
Harquahala Basin	Lower Gila Basin
McMullen Valley Basin	Parker Basin
Ranegras Plain Basin	San Simon Wash Basin
Tiger Wash Basin	Western Mexican Drainage Basin
Yuma Basin	

Volume 8 Active Management Area Planning Area (5 AMAs)

Phoenix AMA | Pinal AMA
Prescott AMA | Santa Cruz AMA
Tucson AMA

Volume 9 is an executive summary of the water resource information and issues contained in Volumes 2-8 and includes a discussion of future directions.

Volumes 2-7 contain numerous maps, figures and tables, with accompanying text as applicable, for each of the 46 groundwater basins in rural Arizona. Volume 8 will contain similar information for the AMAs. The AMA volume may contain additional information. Maps, figures and tables, and some of their primary components are listed below. Please refer to the Acronym index for agency and station names.

Basin and AMA Maps and Figures

1. Geographic features
2. Land ownership
3. Precipitation and meteorological stations
   Location of NOAA, NWS, AZMET, Pan ET, SNOTEL and Snowcourse stations keyed to climatic data table
4. Surface water conditions
   Major rivers and streams, unit runoff contours, location of flood warning gages, USGS stream gages, reservoirs $\geq$500 acre-feet keyed to stream gage, flood gage and large reservoir tables
5. Perennial/intermittent streams and major (>10gpm) springs
   Location of perennial and intermittent streams and location of major springs keyed to major springs table
6. Groundwater level conditions
   Current depth to water, groundwater level changes since 1991 in selected wells, general groundwater flow direction, keyed to selected basin hydrographs
7. Selected basin hydrographs
8. Measured and reported well yields
   Well yields measured by USGS and the Department and reported for >10 inch diameter wells
9. Water quality conditions
   Location of wells, springs and mine sites with drinking water exceedences, impaired lakes and stream reaches, and effluent dependent reaches, keyed to water quality exceedences table
10. Location of water uses
    Active agricultural lands, power plants, large mines and water provider service areas
11. Water adequacy and inadequacy determinations
    Location of Water Adequacy and Inadequacy determinations issued, keyed to table with subdivision information and reason for the inadequacy determination

Basin and AMA Tables

1. Climatic data
   - NOAA and NWS stations: name, period of record, elevation, minimum and maximum average temperature, average seasonal and average annual rainfall
   - Pan Evaporation stations: name, period of record, elevation, average annual evaporation
   - AZMET stations: name, period of record, elevation, average annual reference ET

- SNOTEL/Snowcourse stations: name, period of record, elevation, monthly snow water equivalent

2. Stream gage data
   - Streamflow: gage name, drainage area, period of record, total years of record, mean basin elevation, average seasonal flow, minimum, median, mean and maximum annual flow
   - Flood/ALERT gages: name, identification number, station type, installation date, operator
3. Large and small reservoirs and stockponds
   - Large reservoirs (>500 acre-feet or 50 acres or greater surface area): name of lake/reservoir and dam, owner/operator, maximum storage/surface acres, purpose/use, jurisdiction
   - Small reservoirs, (15 to 500 acre-feet or 5 to <50 acre surface area): total number and maximum storage/surface acres
   - Stockponds (up to 15 acre-feet capacity): total number
4. Springs
   - Major springs (10 gpm or greater): name, location, discharge rate, measurement date
   - Minor springs (1 to 10 gpm discharge): name, location, discharge rate, measurement date
5. Groundwater data: basin area, major aquifer(s), well yields, estimated natural recharge and groundwater in storage,number of index wells, date of last well sweep
6. Water quality exceedences
   - Wells, springs and mines: site type, location, water quality standard, parameter(s) exceeded
   - Lakes and streams: site type, name, length of impaired stream reach/area of impaired lake, water quality standard, parameter(s) exceeded
7. Effluent generation: facility name/ownership, city/location served, volume treated, disposal method, treatment level, population served/not served, year of record
8. Cultural water demand: historic, current and projected population, historic and current number of wells < 35gpm and >35gpm, historic and current agricultural, municipal and industrial surface water diversions and groundwater pumpage
9. Water adequacy and inadequacy determinations: subdivision name, application number, location, number of lots, water provider and reason for inadequate determination

SECTION 1.2 Background

1.2.1 Geography

Arizona encompasses about 114,000 square miles of land with great geographical diversity. Hydrologically, the state has been divided into groundwater basins and sub-basins within those basins. These groundwater basins and sub-basins do not necessarily correspond with surface watersheds and subwatersheds, due in part to subsurface geology that can impact groundwater flow and cause it to vary from surface water drainage patterns. There are three main geographic regions or physiographic provinces in the state: the Basin and Range Lowlands, the Plateau Uplands and the Central Highlands Provinces. The provinces and their relationship to the planning areas are shown in Figure 1-2.

Figure 1-2 Physiographic Provinces of Arizona

The Basin and Range Lowlands Province of southern and western Arizona is characterized by long, broad, alluvial valleys separated by north-south trending mountain ranges. Thick, productive regional aquifers are found in this province. The Upper Colorado River, Lower Colorado River and Southeastern Arizona Planning Areas are primarily within the Basin and Range Lowlands Province, which include the communities of Kingman, Lake Havasu City, Yuma, Sierra Vista and Safford. With the exception of the Prescott AMA, the AMA planning area is within this province including the large metropolitan areas of Phoenix, Tucson and Casa Grande.

The Plateau Uplands Province covers the northern portion of the state and is characterized by layered sedimentary rocks that have eroded into canyons and plateaus. The Plateau Uplands Province includes the Eastern Plateau and Western Plateau Planning Areas and a small part of the Central Highlands and Upper Colorado River Planning Areas. This province contains regional aquifers consisting of layered sedimentary rocks and thin deposits of alluvium that form unconfined aquifers along some streams. Communities dependent on the groundwater supplies in this region include Flagstaff, Pinetop-Lakeside, and Kayenta.

The Central Highlands Province is the smallest in terms of area and forms the transition zone between the Basin and Range Lowlands Province and the Plateau Uplands Province. Most of the Central

Highlands Planning Area, the far eastern part of the Upper Colorado River Planning Area, the Prescott AMA and the northern part of the Southeastern Arizona Planning Area are within this province. The province is characterized by a relatively narrow band of mountains composed of igneous, metamorphic and sedimentary rocks. Groundwater is found in thick alluvial deposits, layered sedimentary rocks, thin alluvial deposits along major streams and fractured crystalline, sedimentary and volcanic rocks. (ADWR, 1994a; ADWR, 1994b). Many rapidly growing communities utilize water supplies in this province including Prescott, Sedona, Cottonwood and Payson. This province contains most of the state's perennial streams. Because of high elevations, steep gradients and the predominance of hardrock, much of this area has minimal water storage capabilities and high runoff compared to the Basin and Range Lowlands Province.

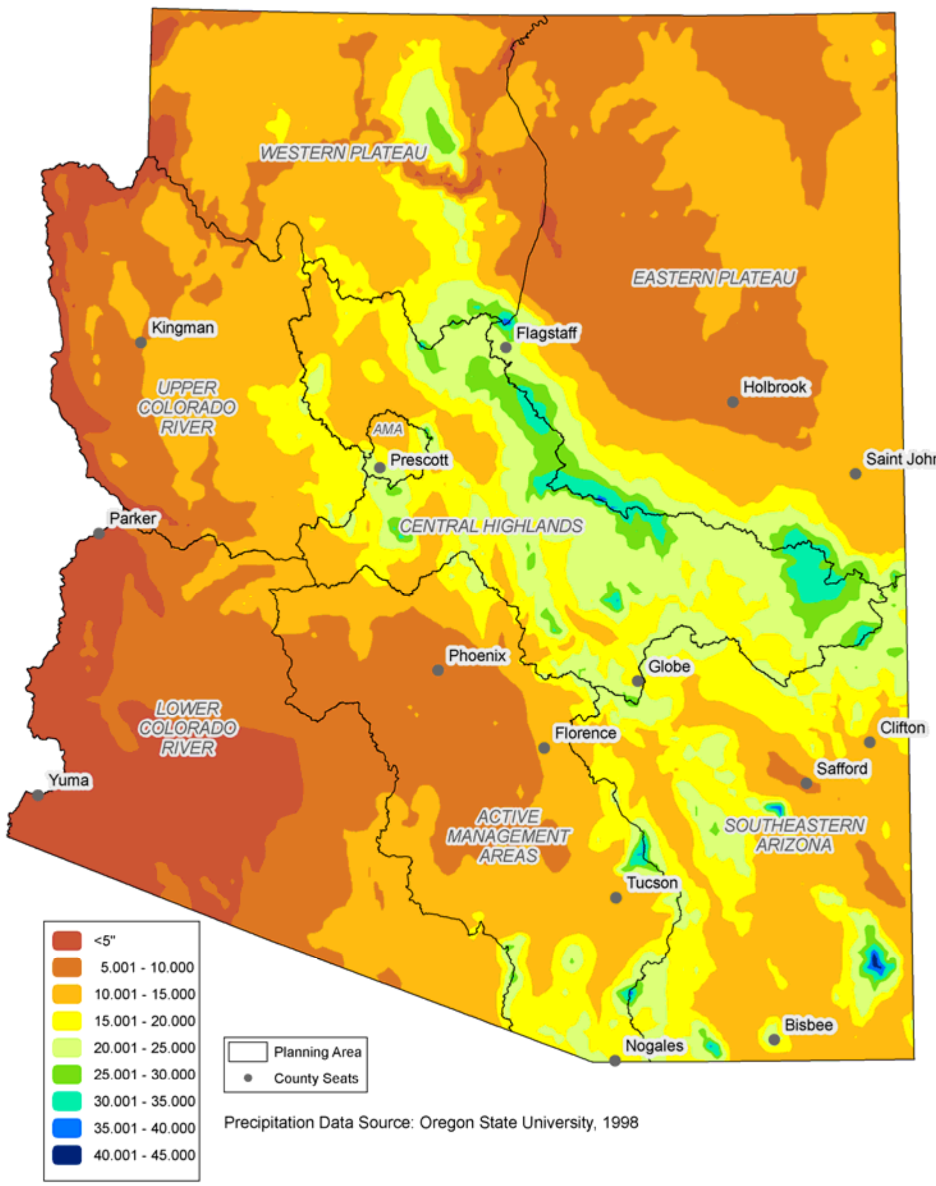
1.2.2 Climate

Climate and drought are discussed in some detail in this section to provide background information and context to the planning area climate data presented in subsequent Atlas volumes. Climate information is a critical component of water resource planning and management.

Arizona's climate is characterized by five main features: warm temperatures, aridity, strong precipitation seasonality, high year-to-year (interannual) variability and strong decade-to-decade persistence. The wide elevational differences result in significant climate variability between the mountains of the Central Highlands Province and the low elevation deserts. The Plateau Uplands Province, although relatively high in elevation, is very dry. Average annual rainfall in Arizona ranges from 3 inches in Yuma to over 36 inches in the higher elevations along the Mogollon Rim and in the White Mountains. State precipitation variability is shown in Figure 1-3.

Precipitation is characterized by two climatically unrelated precipitation seasons: the summer, "monsoon" season, generally from July to mid-September and a winter season from November through mid-April (Figure 1-4). This seasonality is more pronounced in the east-central (Central Highlands Planning Area) and southeastern (Southeastern Arizona Planning Area) parts of the state where the summer precipitation can account for up to 60 percent of the annual total. By contrast, the Upper Colorado River Planning Area receives the majority of precipitation in the winter. Statewide, mid-April through June are reliably dry, as westerly winds shift to the north and the monsoon circulation begins to develop. Mid-September through early November is usually dry, but eastern Pacific tropical storms can cause high precipitation during this time of year.

Figure 1-3 Statewide Precipitation



The summer precipitation season occurs when moist, tropical, unstable air from the Gulf of Mexico moves northwest into Arizona. Storms of short duration but high intensity occur in the afternoon and evening as the warm, moist air is forced up mountain slopes and sufficiently cooled. These storms are typically most intense over the mountainous sections of the state. Winter rains occur when middle latitude cyclonic storms originating in the Pacific Ocean move east across the state. More than 75% of the winter precipitation falls as snow in the higher elevations. (ADWR, 1994a; ADWR, 2005).

Figure 1-4 Average statewide Arizona monthly precipitation and temperature, 1971-2000

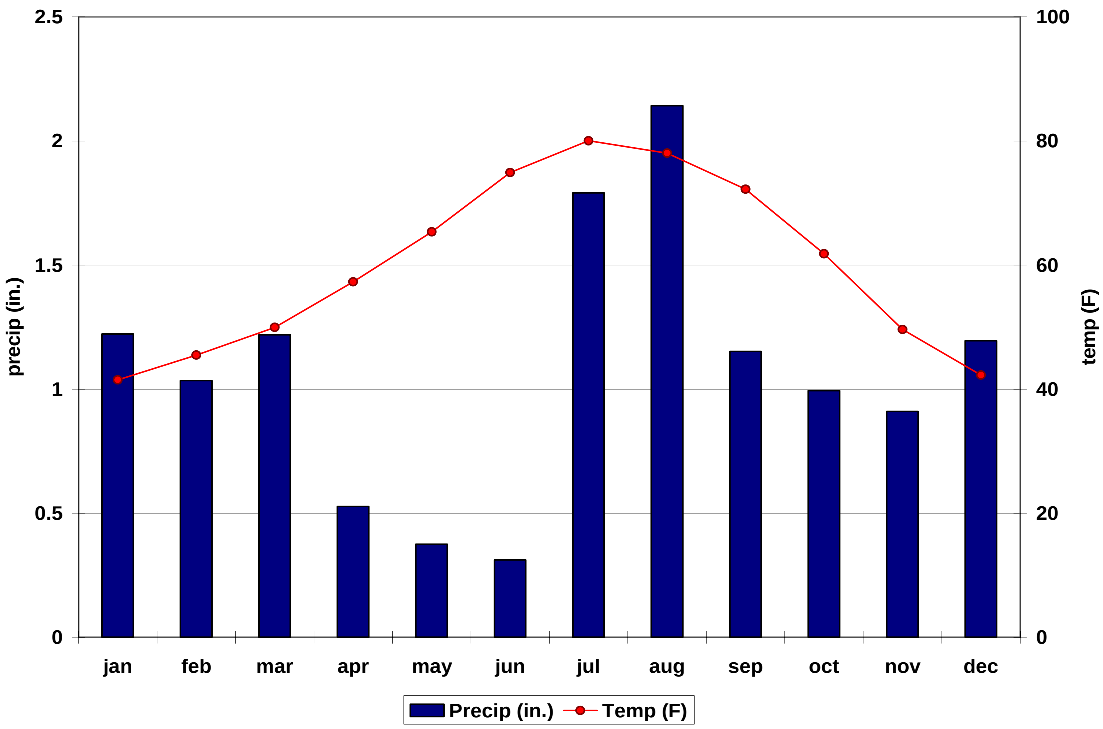


Figure author: Michael Crimmins, University of Arizona Cooperative Extension.

Arizona's precipitation is characterized by a high degree of year-to-year variation. One of the key factors, during winter in particular, is the El Niño-Southern Oscillation (ENSO), a multi-season to multi-year variation in equatorial Pacific Ocean temperatures and associated atmospheric circulation. The ENSO is the strongest and most important influence on interannual climate and weather variations in Arizona. When El Niño-Southern Oscillation is in the El Niño phase, Arizona frequently receives above average winter precipitation. When El Niño-Southern Oscillation is in the La Niña phase, Arizona is frequently dry due to a more northern storm track. These phases recur every 3 to 7 years on average and can persist for months to years, impacting precipitation totals over Arizona. During the past two decades, several La Niña episodes (e.g. 1989-90, 1995-96, 1998-2001) have initiated Arizona droughts (GDTF, 2004a). The La Niña of 2005-2006 resulted in virtually no snowpack in Arizona until mid-March, with 29 of the 34 snow measuring sites monitored by the NRCS reporting no snow as of March 1, 2006, the least amount recorded since measurements began in the late 1930's.

Arizona's Colorado River water supplies derive primarily from snow in the western Rocky Mountains of Wyoming, Colorado, and Utah, whereas Arizona surface water supplies, such as in the Salt and Verde River systems, derive chiefly from snow along the Mogollon Rim and high peaks on the Colorado Plateau.

Winter precipitation is more hydrologically effective than summer precipitation because winter precipitation is more widespread, is generally of low intensity and long duration, it coincides with cooler temperatures and lower evaporation rates and, when stored as snow, it is released gradually. These factors result in greater infiltration than summer rainfall events, where rain falls in the form of spatially discontinuous thunderstorms and is subject to extremely high evaporation rates.

Temperature and associated evapotranspiration rates also vary widely in Arizona. Average daily temperatures range from the mid 90's (˚F) below 500 feet elevation to the high 50's (˚F) at elevations above 8,000 feet. In most areas of the state, temperatures increase 30 to 40 degrees between January and July (ADWR, 1994a). Climate can also vary widely within planning areas. Measured climate data are described in detail in the planning area volumes.

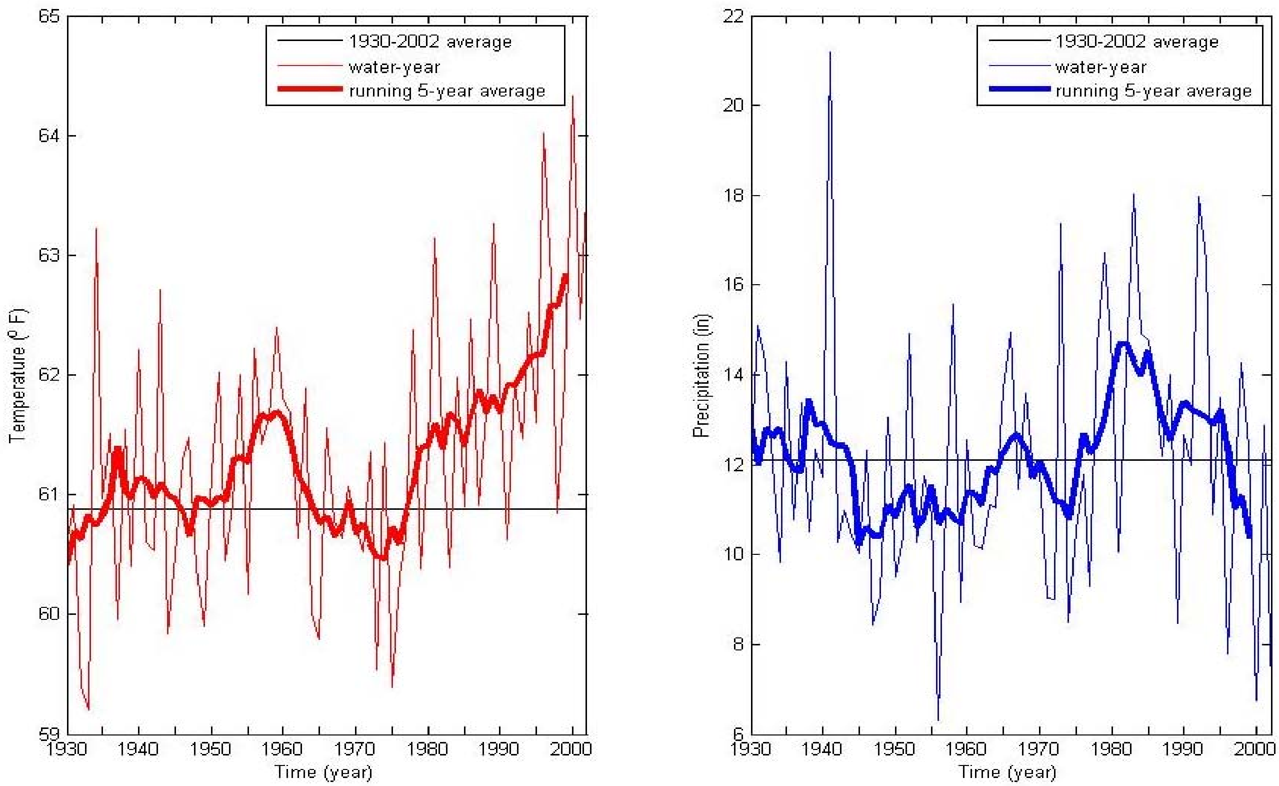
The most significant feature of temperature records since 1930 is the trend toward increasing temperatures during the last 30-40 years (Figure 1-5). In some regions, increased temperatures are due primarily to the urban heat island effect from heat-retaining paved area and buildings replacing desert landscapes in major urban areas. Temperatures in rural communities have also increased, though not at the same rate and not in every town. The mid-to-late twentieth century is the warmest period in a southern Colorado Plateau tree-ring temperature reconstruction (Salzer and Kipfmueller, 2005), as well as in reconstructions of summer season precipitation for a region stretching from west Texas to eastern California (Sheppard et al., 2002). High temperatures typically result in higher cultural water demands and increased evaporation and evapotranspiration rates.

Drought

Decadal-scale Pacific Ocean circulation persistence can result in long-term drought, which can drastically reduce water supplies as demonstrated in the extremely dry conditions between 1999 and 2005 and during the 1950s. Table 1-1 shows that 2004 was the year of lowest capacity in most of the state's reservoirs during the period of 1971-2005. When these sustained circulation patterns are characterized by warm tropical Pacific Ocean temperatures, the result can be above average precipitation such as the post-1976 wet period which lasted until approximately 1998 (Figure 1-5). This wet period is also reflected in the high capacity reservoir level data in Table 1-5. Some reservoirs, including Lake Powell and Lake Mead, exceeded their maximum useable capacity during this period and spilled.

When Arizona's high interannual precipitation variability is superimposed on persistent decadal variations, the result is individual wet years during periods of prolonged drought. This is shown in Figure 1-5.

Figure 1-5 Average water-year (October-September) temperature (left) and total water-year precipitation in Arizona from 1930-2002



Horizontal lines are average temperature (60.9 °F) and precipitation (12.1 in), respectively. Light lines are yearly values and highlighted lines are 5-year moving average values. Data are the average of monthly records from 25 U.S. Historical Climate Network (HCN) stations from the National Climate Data Center (http://cdiac.ornl.gov/epubs/ndp/ushcn/monthly.html). Figure author: Ben Crawford, CLIMAS.

Table 1-1 Arizona mean, high capacity and low capacity reservoir levels from 1971 through 2005, expressed in percent of total reservoir capacity (design flood pool)

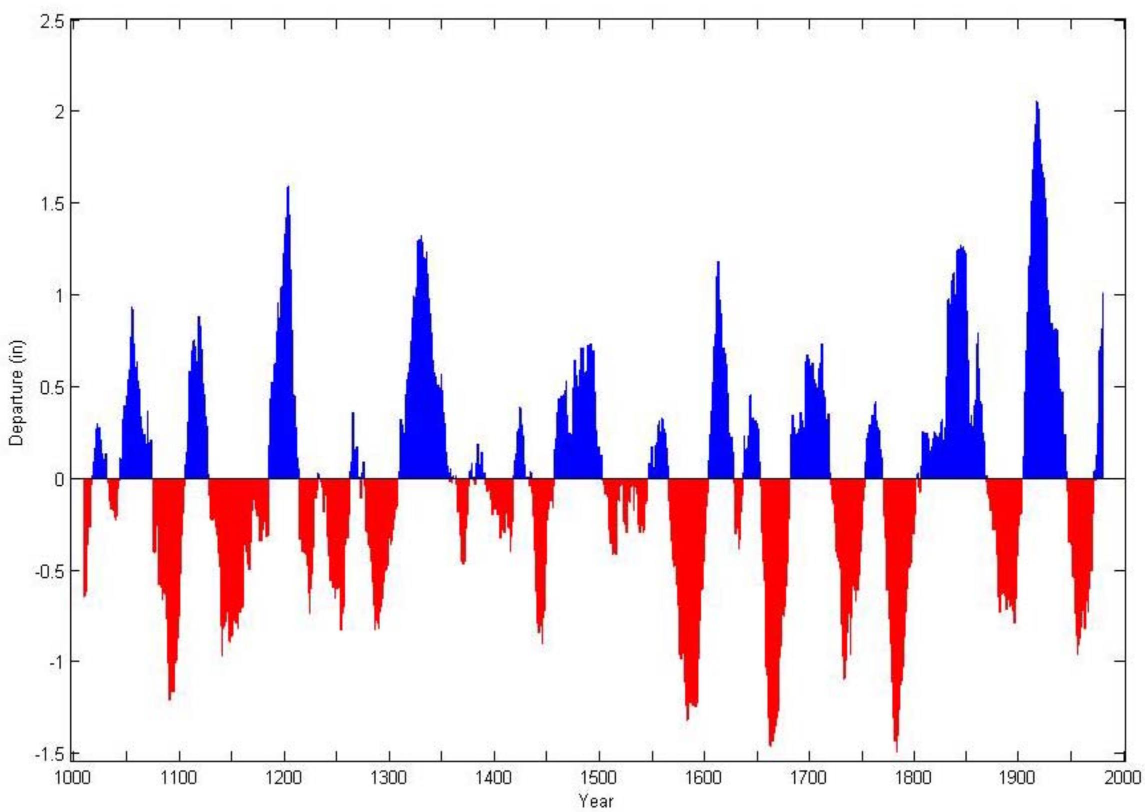
Reservoir Name	Average Capacity	High Capacity	High Capacity Year	Low Capacity	Low Capacity Year
Lake Powell	70%	98%	1983	31%*	2005
Lake Mead	77%	98%	1983	51%	2004
Lake Mohave	89%	98%	1971	74%	2000
Lake Havasu	88%	96%	1982	77%	1980*
Show Low Lake	62%	100%	1993	58%	2004
Lyman Reservoir	45%	86%	1985	11%	2004
San Carlos	42%	100%	1980	3%	2004
Verde River Basin System	56%	91%	1992	43%	2004
Salt River Basin System	59%	77%	1979	43%	2004

Sources: USDA Natural Resources Conservation Service, Casey C. Thornbrugh, CLIMAS.
USBR data, Don Gross, ADWR
* Lake Havasu 2004 low capacity was 79%

Tree-ring records of drought and winter precipitation show dry episodes longer and more severe than any that have occurred during the last 100 years. In Arizona, notable multi-year droughts occurred in almost every century in the last 1,000 years. Particularly notable are winter-season droughts during the 1100s, the 1200s, the early 1400s, the late 1500s, the late 1600s, the late 1700s, the late 1800s and the mid-1900s (Figure 1-6). Tree-ring records of Colorado River streamflow show periods of extended low flows, such as those in the 1580s, the early 1620s to 1630s, the 1710s, the 1770s, and the 1870s (C. Woodhouse, NOAA Paleoclimate Program, personal communication to G. Garfin, 2005). These episodes were either more severe or longer in duration than low flow periods experienced in more recent times. The low flow period of the late 1500s is associated with widespread drought conditions across North America (Stahle et al., 2000).

Such periods of widespread drought are characterized by low stream flows in the Upper Colorado River Basin as well as interior Arizona river basins, such as the Salt-Verde-Tonto river system. Records show that the Upper Colorado River Basin streamflow is seldom out of synch with Salt-Verde-Tonto river system streamflow (Hirschboeck and Meko, 2005; http://fp.arizona.edu/khirschboeck/srp.htm). This has serious implications for water supply availability in parts of Arizona.

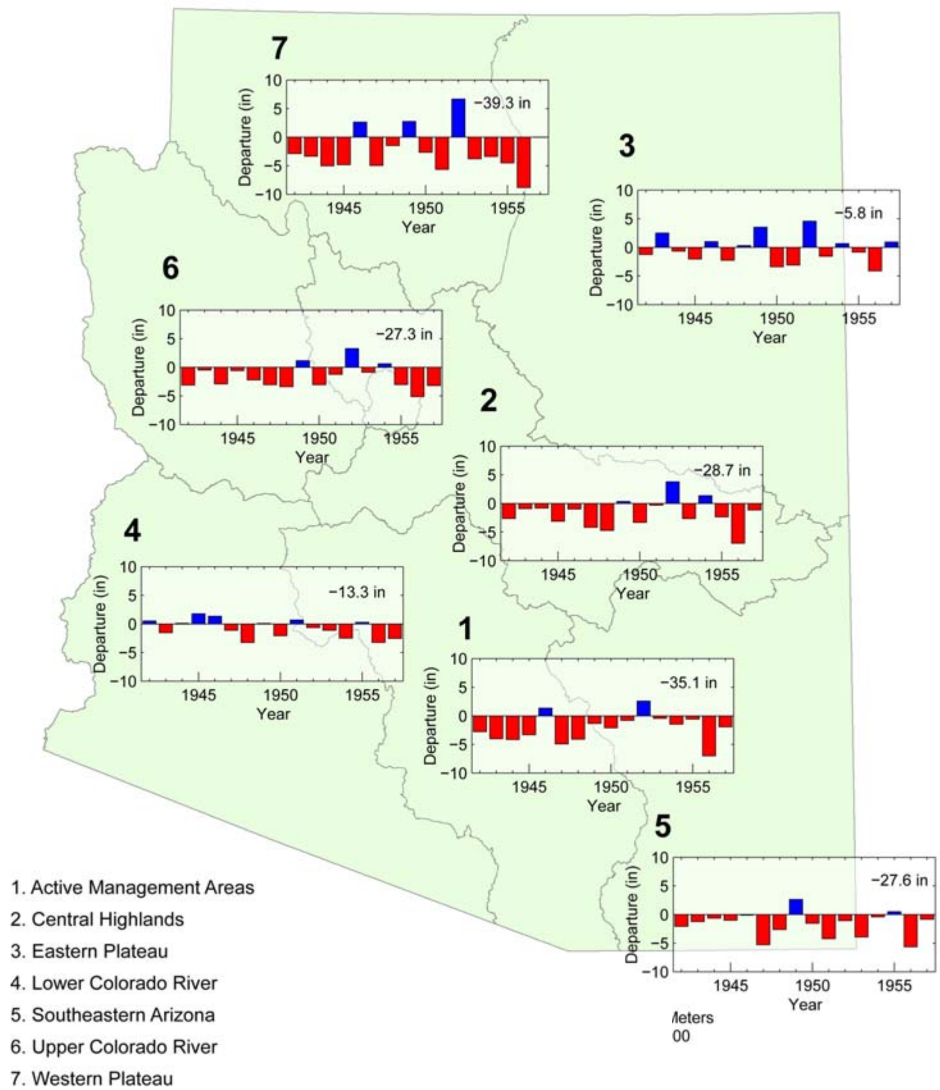
Figure 1-6 Arizona statewide winter half year (November-April) precipitation departures from average (shown as 0), 1000-1988, reconstructed from tree rings



Data are presented as a 20-year moving average (e.g. the value for 1951 is the average of 1942-1961) to show variability on decadal time scales. The statewide winter half-year average precipitation for 1000-1988 is 5.8 in. annually. Data: Fenbiao Ni, University of Arizona Laboratory of Tree-Ring Research and CLIMAS. Figure author: Ben Crawford, CLIMAS.

Planning area and AMA water deficits for the prolonged drought of 1942-1957 are shown in Figure 1-7. It is evident that planning areas were affected to varying degrees during this period. For example, the Eastern Plateau Planning Area was the least impacted, with many years of above normal precipitation and a modest cumulative deficit of -5.8 inches over the drought period. While the current drought may reflect similar precipitation conditions to those of the drought of the late 1940s to 1950's, temperatures during the last decade are almost 2 degrees higher (see Figure 1-5). This warming trend will affect the severity of drought conditions.

Figure 1-7 Planning area water-year (October-September) precipitation departures from average for the 1942-1957 drought period



For each planning area, data from U.S. Historical Climate Network (HCN) stations from the National Climatic Data Center (http://cdiac.ornl.gov/epubs/ndp/ushcn/monthly.html) were used to calculate the total departure (upper right of each bar graph). Figure author: Ben Crawford, CLIMAS.

1.2.3 Water Resources Overview

Colorado River Water and the Central Arizona Project

Arizona has an annual allotment of 2.8 million acre-feet (maf) of Colorado River water for consumptive use. Consumptive use (CU) is defined here as diversions from the mainstream of the Colorado River minus returns. Of this total, over 1.3 maf of CU is available for use by municipal, industrial and agricultural users along the Colorado River in the Upper and Lower Colorado River Planning Areas. In addition, the community of Page in the Eastern Plateau Planning Area diverts water from Lake Powell for municipal use pursuant to Arizona's 50,000 acre-feet Upper Basin entitlement. The remaining amount of Colorado River water may be diverted annually via the Central Arizona Project (CAP) delivery system to users in the Phoenix, Tucson and Casa Grande areas. (Figure 1-1). CAP water is diverted from the Colorado River at Lake Havasu into a 336-mile aqueduct system that lifts the water more than 2,900 vertical feet through a series of pumping plants to users in central Arizona. The Central Arizona Water Conservation District (CAWCD) operates and maintains the CAP.

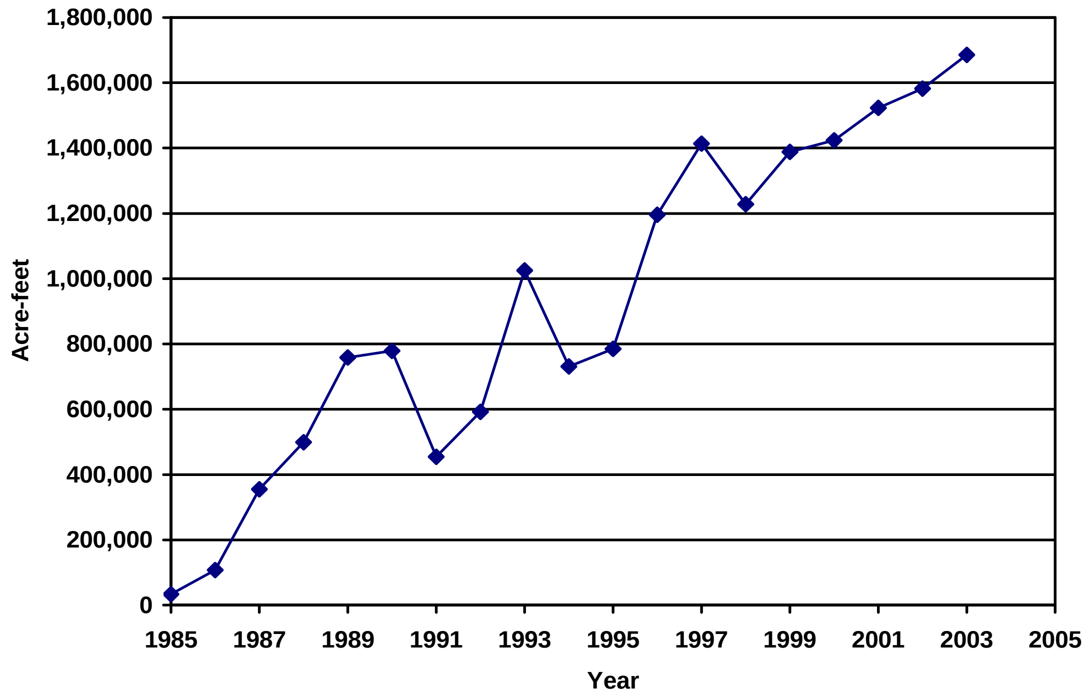
When the entitlements to Colorado River water were identified in the Colorado River Compact in 1922, the River data showed an average annual flow of approximately 16.4 million acre-feet at Lees Ferry below Lake Powell (See Appendix E). However, recent analysis of three centuries of river flow indicates an average annual flow of 13.5 maf, and very erratic annual flows, ranging from 4.4 maf to over 22 maf (Gelt, 1997). A tree-ring based assessment completed in 2005 found that for the period 1521-1964, the mean annual flow at Lees Ferry was about 14.2 maf (Hirschboeck and Meko, 2005). This situation highlights the importance of the Colorado River dams and reservoirs to store water for use during dry periods. Currently, the Lower Basin (Arizona, California and Nevada) is fully utilizing its 7.5 million acre-foot annual entitlement. Upper Basin (Colorado, New Mexico, Utah and Wyoming) demand is approximately 5 million acre-feet per year and Mexico is utilizing its full 1.5 million acre-foot per year entitlement.

There is a priority system associated with Colorado River contracts in the event of shortages of supply. Contract priority is an important consideration in water resource planning. The first water to be shorted within Arizona is the CAP and water users of similar priority along the mainstream of the Colorado River. Along the Colorado River the communities of Bullhead City, Lake Havasu City, and Mohave Valley Irrigation District in Mohave County, and Ehrenberg, Parker and Cibola Irrigation District in La Paz County have low priority contracts. The City of Yuma and the Wellton-Mohawk Irrigation District in the Lower Colorado River Planning Area have higher priority contracts.

The Arizona Water Banking Authority (AWBA) was established in 1996 to store unused Colorado River water to meet future needs. Without the AWBA, Arizona may not have used its full allocation for many years. The primary functions of the AWBA are: to provide a stored reserve of water to communities dependent on the CAP during times of drought on the Colorado River; to assist Colorado River communities during times of shortage by providing water exchange mechanisms; to replenish depleted aquifers with CAP water to meet water management goals; to provide a pool of water for use in Indian water rights settlements. The AWBA can also contract with similar authorities in California and Nevada to allow these states to annually store unused Colorado River water in Arizona. In the future, Arizona users will recover (pump) the stored water (less a 5% "cut to the aquifer") and the interstate partner will draw a similar quantity directly from the Colorado River.

Shown in Figure 1-8 are annual diversions of CAP water from the Colorado River. The amount of water diverted over the years varies for several reasons, including demand and supply availability due to a number of different conditions. The AWBA, the in-lieu recharge program and CAP pricing structures for agricultural users have promoted CAP utilization since the mid-1990s.

Figure 1-8 Central Arizona Project annual diversions 1985-2003



Other Surface Water

The Salt, Verde and Gila Rivers are essential supplies for water users in central Arizona. The Salt River Project (SRP), through the Salt River Valley Water Users' Association, a private corporation, delivers a total of almost 1 million acre-feet of surface water from the Salt and Verde Rivers and groundwater to its service area in the Phoenix AMA. SRP manages several dams on the Salt and Verde Rivers that produce hydroelectricity and has substantial surface water rights in the Salt and Verde watersheds. These claims have implications for rural water users in these watersheds. Water supplies utilized by the towns of Cottonwood, Clarkdale, Camp Verde, Payson and others are derived from the watersheds of the Salt and Verde Rivers. The water supplies of the upper Gila River communities of Safford, Thatcher and others are impacted by senior surface water rightholders downstream of their communities and by Indian water rights settlements. Surface water from the Gila River (pursuant to the Globe-Equity Decree), has historically been the primary water supply for the San Carlos Irrigation and Drainage District in the Pinal AMA (see Appendices A and E).

In other parts of Arizona, local surface water supplies are used by municipal, industrial and agricultural users. Principal surface water resources include the Little Colorado River, San Pedro River, Verde River, other rivers and streams, captured runoff in reservoirs, and springs. These supplies may be more drought sensitive than the larger regional systems. Communities that utilize surface water include, Eager, Flagstaff, Jerome, Tombstone and Williams. Industrial users of substantial volumes of surface water include the Navajo Generating Station at Page, the Southpoint Power Plant in the Lake Mohave Basin, and the Morenci Mine in the Morenci Basin. Surface water is used for agricultural irrigation in several basins in the Eastern Plateau, Central Highlands and Southeastern Arizona Planning Areas, including agricultural users in the Verde River, Upper San Pedro and Salt River Basins. A more detailed description of surface water supplies is found in Volumes 2-8.

Groundwater

Groundwater is an important water supply for many water users across the state. However, while a number of hydrologic studies and groundwater models have been completed in the AMAs, there is often less known about the groundwater conditions outside AMAs. Although the Department conducts water level and water quality measurements periodically outside AMAs, fewer comprehensive studies have been done in these areas.

Some areas of the state have relatively deep alluvial aquifers with substantial amounts of groundwater in storage. This is generally true for the southern part of Arizona including much of the Pinal, Phoenix and Tucson AMAs. In other areas however, hydrologic conditions are less favorable. Aquifers may be thin or unproductive, particularly in mountainous areas, or depth to groundwater may be very great. This is the case in the Payson area and in much of the Santa Cruz AMA, where thin or fractured aquifers make them responsive to precipitation events and susceptible to drought. Poor water quality can also be an issue. For example, some of the regional aquifers of the Eastern Plateau are characterized by high levels of total dissolved solids, and in some cases are unsuitable for use.

With the exception of the Lower Colorado River Planning Area, groundwater is the primary water supply utilized outside AMAs for cultural uses. This is also the case within the AMA planning area. In 2003, groundwater was the primary water supply utilized in every AMA. As drought and growth stress the availability of surface water supplies, communities that historically have relied on surface water are exploring groundwater resource options including drilling additional wells and acquiring land for wellfield development. Groundwater conditions are described in more detail for each planning area in Volumes 2-8.

Effluent

Access to renewable water supplies, especially outside AMAs, may be physically or legally limited. An exception is effluent, which increases with sewered population growth. Effluent is currently utilized in a number of communities for turf irrigation and recharge. Communities outside AMAs that reuse effluent for irrigation include Benson, Flagstaff, Lake Havasu City, Payson, Sierra Vista, and Yuma. Fort Huachuca and the City of Sierra Vista recharge effluent at constructed recharge facilities. Other communities have plans for reuse in the future.

Effluent is an important supply in the Tucson and Phoenix AMAs. Almost 68,000 acre-feet of effluent was delivered to the Palo Verde Nuclear Generating Station in the Phoenix AMA for cooling purposes in 2003. Another 34,100 acre-feet was delivered to municipal and industrial users for park and golf course irrigation. In the Tucson AMA almost 10,000 acre-feet was delivered for turf irrigation use in 2003.

Cultural Water Demand

Cultural water demand refers to the quantity of water diverted from streams and reservoirs, pumped from wells or treated and delivered for municipal, industrial and agricultural purposes. This term should not be confused with “consumptive use”, which refers to the amount of the cultural water demand that is lost from the hydrologic system. For example, not all surface water diverted to irrigate crops is permanently lost; a portion of the water applied to fields may flow back to streams (return flow) or infiltrate to underlying aquifers (incidental recharge). Similarly, a portion of the water pumped from wells to meet municipal demands is incidentally recharged or can be recovered as effluent from wastewater treatment plants.

Data sources and the methods used to estimate cultural water demands for the Atlas, as well as the limitations of these estimates, are described in Section 1.3.5, *Cultural Water Demand*. Data presented here provide a general assessment of water demands in Arizona by municipal, agricultural and industrial users. Sectors are defined similarly to those used for the AMAs and definitions of these sectors are found in the *Definitions* section.

Water demand data within AMAs is collected annually by the Department, but reporting issues, agency priorities and the complexity of the water accounting systems have prevented consistent, annual compilation of each AMA’s data. Outside AMAs, annual water use reporting to a designated agency is the exception. Private water companies must annually report pumpage and deliveries to the Arizona Corporation Commission (ACC) but information on water use by other water providers, including public utilities and water improvement districts, must be gathered separately. Agricultural and industrial water use by individual water users is not typically reported regularly to any agency. The primary data source for well pumpage outside of AMAs was the USGS 2005 report *Water Withdrawals for Irrigation, Municipal, Mining, Thermoelectric-Power, and Drainage Uses in Arizona Outside of Active Management Areas, 1991-2000* and supporting data. The USGS 2005 report also includes surface water diversions for agricultural use where metered. In areas where surface water diversions are not metered, the Department estimated the diversions by sector. Therefore, the water demand estimates in Table 1-2 are compiled from a variety of sources, which should be taken into consideration when interpreting the estimates.

Table 1-2 AMA water demand data is primarily from 2003 water withdrawal and use reports submitted by groundwater rightholders. Indian demand is generated primarily from CAP and other delivery reports (for agriculture) and estimates of population and GPCD (for municipal). Exempt well demand is estimated from the number of domestic, exempt wells. Detailed information about water supply and demand is provided by basin for areas outside of AMAs in Volumes 2-7 and for AMAs in Volume 8.

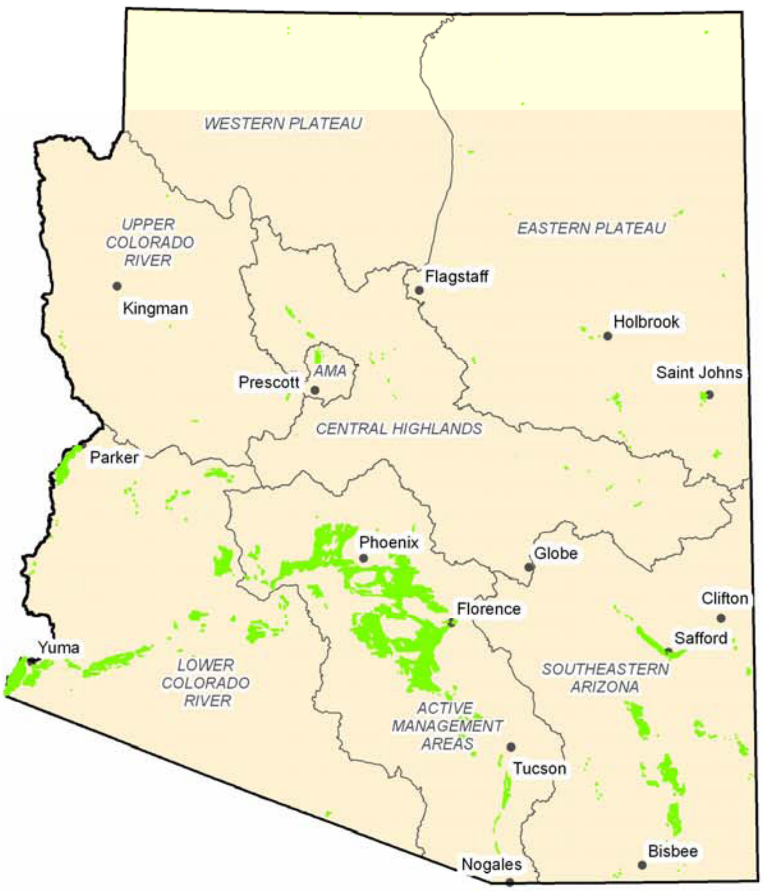
Table 1-2 Cultural water demand by non-AMA and AMA water demand sectors in 2003.

Water Demand Sector/Supply	AMA Demand (acre-feet)	Non-AMA Demand (acre-feet)
Municipal	**1,369,100**	**197,600**
SW	373,900	44,300
GW	479,300	153,300
CAP[1]	421,900	----
Effluent	94,000	ND
Agricultural	**1,767,400**	**3,669,100**
SW	165,700	2,132,000
GW	947,300	1,537,100
CAP[2]	585,000	----
Effluent	69,400	ND
Industrial	**222,100**	**180,700**
SW	24,800	41,900
GW	173,700	138,800
CAP[3]	1,800	----
Effluent	21,200	----
Other[4]	600	----
Indian	**420,600**	**Use included above**
SW	130,300	----
GW	145,100	----
CAP[5]	140,000	----
Effluent	5,200	----
Total	**3,779,200**	**4,047,400**

ND = not determined
[1] Includes direct use and recharge credit recovery
[2] Includes direct use and in-lieu. (see definitions section)
[3] All CAP used is “direct use”, no in-lieu
[4] Multiple water supplies that cannot be separately determined
[5] All CAP used is direct use

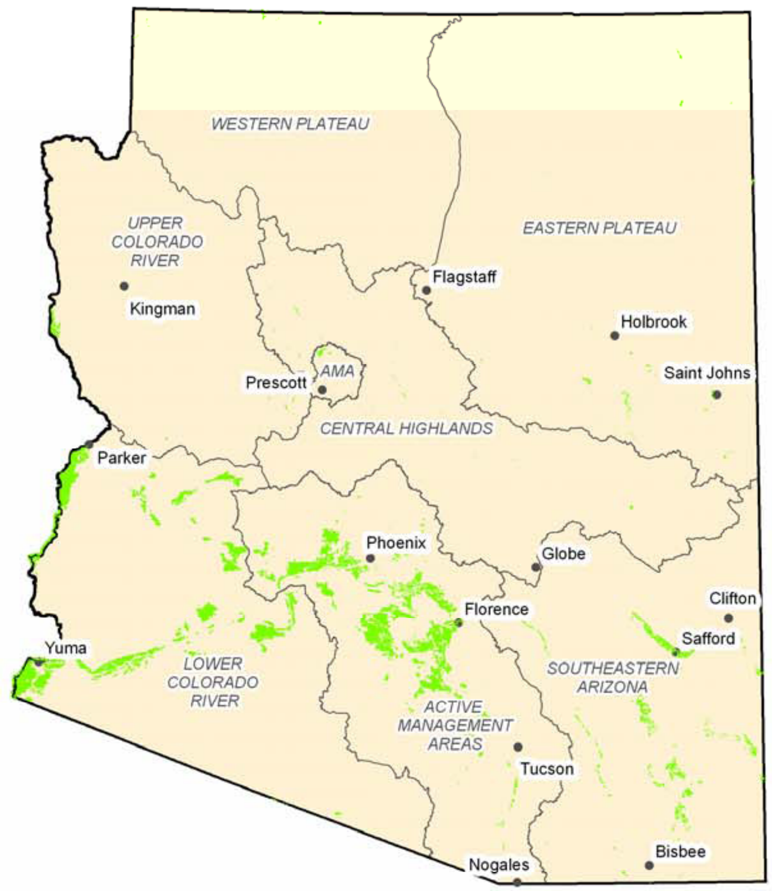
Total cultural water demand was greater outside AMAs than within AMAs in 2003. The demand associated with the AMA population centers and the large volume of agricultural water use outside AMAs is clearly shown in Table 1-2. The agricultural sector is the largest cultural water demand sector both within and outside AMAs and the volume of agricultural water use outside AMAs is almost as large as the total cultural water demand within AMAs. The extent and distribution of irrigated agricultural land in Arizona is shown for circa 1970 and 2000 in Figure 1-9. The resolution of the older map is of lesser quality than the more recent map but in general, agriculture has declined in most planning areas with the exception of the Lower Colorado River. There were notable agricultural declines in the AMAs and in parts of the Southeastern Arizona Planning Area. Industrial demand is relatively comparable within and outside AMAs.

Figure 1-9 Agricultural lands in Arizona, Circa 1970 and 2000



Agriculture
Circa 1970

Primary Data Source: Arizona Crop and Livestock Reporting Service, 1973



Agriculture
2000

Primary data Source: USGS National Gap Analysis Program, 2004

Figures 1-10 and 1-11 show the water supplies utilized within AMAs and water supplies utilized outside AMAs by source and percentage of the total supply. Groundwater is water pumped from wells while surface water is water diverted from streams and springs. CAP refers to all CAP used including CAP water used "in-lieu" of groundwater pumping by the agricultural sector and recovery of CAP recharge credits by municipal users. In AMA water budgets, the "in-lieu" CAP is accounted for as a "debit" to the groundwater supply because credits are accrued by the "storer" that may recovered in the future through groundwater pumping. Effluent is also used outside of AMAs but it was not possible to quantify the demand. It is expected that this supply is less than 1% of the total.

Figure 1-10 Water supplies utilized by cultural water demand sectors within AMAs in 2003 (by source and percentage of total)

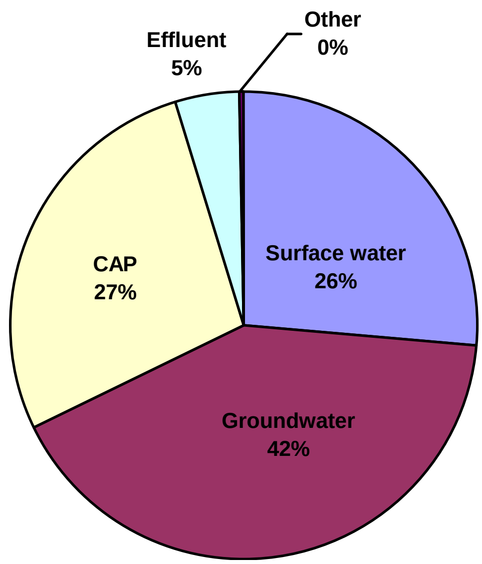


Figure 1-11 Water supplies utilized by cultural water demand sectors outside AMAs in 2003 (by source and percentage of total)

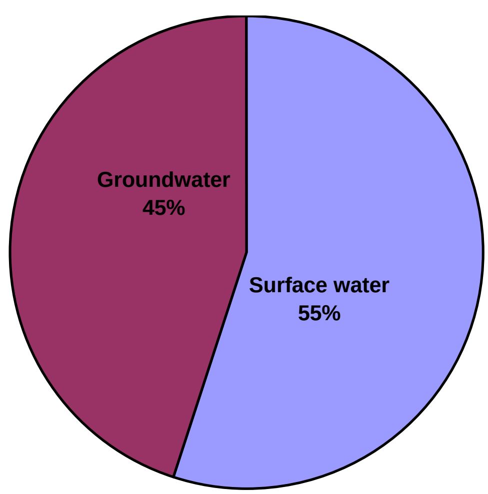


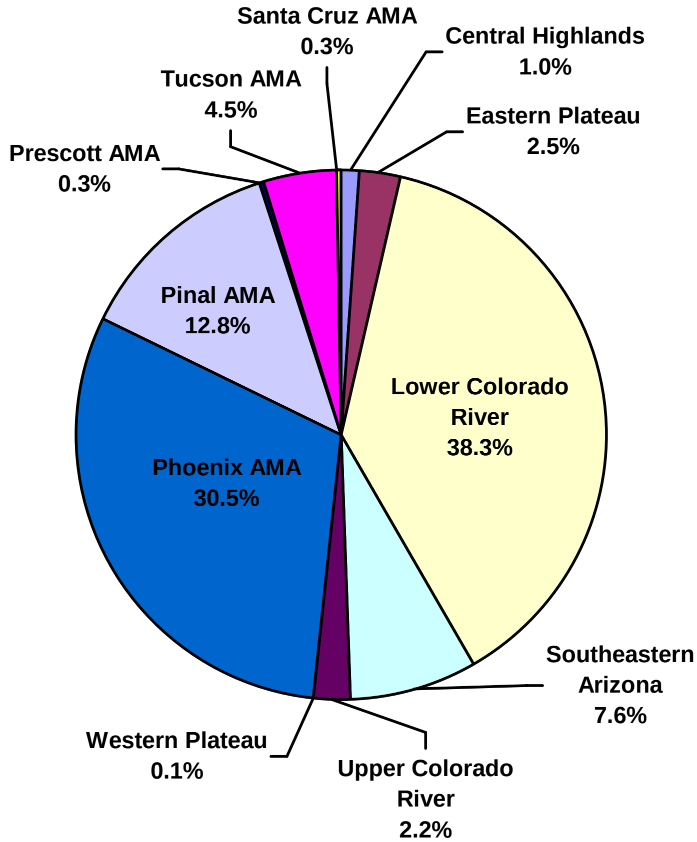
Table 1-3 provides a summary of water demand by sector and water supply for each of the non-AMA planning areas. Water demand varies significantly by volume, source of water and by sector. For example, agricultural surface water diversions in the Lower Colorado River Planning Area are almost 73% of all the water used outside AMAs, and agricultural and industrial water demand vary significantly between planning areas. The importance of groundwater as a municipal supply in most planning areas is evident. Agricultural water demand is the largest demand sector by far in all but one of the planning areas and is served by significant amounts of both surface and groundwater. Industrial demand, (associated with power plants, mining, dairies, feedlots and turf irrigation), is a significant percentage of the total water demand in all planning areas (7% to 42%) with the exception of the Lower Colorado River. Figure 1-2 shows the relative water demand of each planning area as a percentage of the total state water demand.

Table 1-3 Non-AMA planning area cultural water demand by sector in 2003 (in acre-feet)

SECTOR/ SUPPLY	PLANNING AREA					
	Central Highlands	Eastern Plateau	Lower Colorado River	South-eastern Arizona	Upper Colorado River	Western Plateau
Municipal	**25,000**	**30,200**	**50,000**	**38,300**	**51,200**	**2,900**
Surface Water	4,000	4,200	34,000	300	700	1,100
Groundwater	21,000	26,000	16,000	38,000	50,500	1,800
Agricultural	**36,000**	**83,000**	**2,940,000**	**514,000**	**92,000**	**4,100**
Surface Water	22,500	48,500	1,900,000	102,000	57,500	1,500
Groundwater	13,500	34,500	1,040,000	412,000	34,500	2,600
Industrial	**18,900**	**83,000**	**7,900**	**40,300**	**29,500**	**1,100**
Surface Water	7,400	26,500	2,600	1,100	4,000	300
Groundwater	11,500	56,500	5,300	39,200	25,500	800
TOTAL	**79,900**	**196,200**	**2,997,900**	**592,600**	**172,700**	**8,100**

*Planning area totals rounded to nearest thousand if greater than 100,000

Figure 1-12 Each planning area's percentage of total cultural water demand in 2003



Water Budget

A water budget is an accounting of inflows and outflows of water from a basin. Typical surface water and groundwater components of inflow and outflow are listed below. Surface water inflows include: precipitation, surface water entering the basin, baseflow, irrigation return flow and effluent discharge. Groundwater inflows include natural groundwater recharge (mountain front recharge and stream channel recharge from precipitation), groundwater underflow into the basin, artificial recharge from recharge facilities and incidental recharge. Surface water outflows include evaporation from bodies of water, streamflow leaving the basin and diversions for cultural water use. Groundwater outflows include evapotranspiration, groundwater underflow, baseflow to surface water and well pumpage for cultural water use. Cultural water demand is often the largest component of outflow from a basin. Streamflow, (composed of baseflow, snowmelt and precipitation) or groundwater recharge is often the largest component of inflow.

Inflow	**Outflow**
Surface Water	
• Precipitation** • Surface water entering basin from precipitation events and snowmelt ** • Baseflow to surface water* • Irrigation return flow • Effluent discharge*	• Evaporation* • Surface water exiting basin** • Surface water diversions (agricultural, municipal, industrial, stock water)**
Groundwater	
• Natural groundwater recharge** • Groundwater underflow into basin • Artificial and incidental recharge*	• Evapotranspiration (riparian vegetation) • Groundwater underflow exiting basin • Baseflow from groundwater to surface water* • Well pumpage (agricultural, municipal, industrial, stock water)**

* related or cursory data are presented in the Atlas for the component

** detailed data is presented in the Atlas for the component

Estimates of natural groundwater recharge, streamflows, precipitation and cultural water demands in non-AMA planning areas are presented by basin in Volumes 2-7 and for AMAs in Volume 8. Other components of outflow and inflow are not well quantified in the Atlas or are not quantified at all. Those not quantified are often difficult to estimate but should be considered when constructing a water budget. These include incidental recharge, irrigation return flow, baseflow, evapotranspiration, evaporation and underflow. For example, phreatophyte evapotranspiration is difficult to quantify but may represent a large water demand "sector" in some basins, such as in the Upper San Pedro.

Water is often lost from municipal and agricultural water distribution systems due to leaks and breaks from water lines and storage tanks, illegal connections and evaporation. These may represent components of incidental recharge, evaporation, or cultural demand. In some cases water line losses can be significant. One third of the respondents to a system water loss question in the 2003 Rural Water Resources Questionnaire reported losses of over 10% with losses of up to 60% reported. Within AMAs there are system water loss requirements for municipal, agricultural and industrial water users. Reducing system losses eliminates unnecessary pumping and related costs and may postpone or eliminate the need to secure other supplies to meet system water demands.

Evaporative losses are also associated with uncovered agricultural conveyance systems and irrigation. Evaporation from reservoirs and ponds is significant and varies widely across the state. Evaporation rates range from less than 3 feet/year in the mountains of central Arizona to greater than 8 feet/year along the Colorado River in western Arizona (NOAA, 1982). Regardless of the variability, the total quantity of water lost to evaporation from these sources is substantial.

In the 1950's, average evaporative losses from reservoirs and ponds in Arizona were estimated to total 148,000 acre-feet per year (USGS, 1962). By comparison, these losses were estimated to total 198,200 acre-feet per year in the early 1970's (Arizona Water Commission, 1975) and 221,400 acre-feet in 2000 (BOR, 2004). Note that the estimates do not include major reservoirs located along the Colorado River.

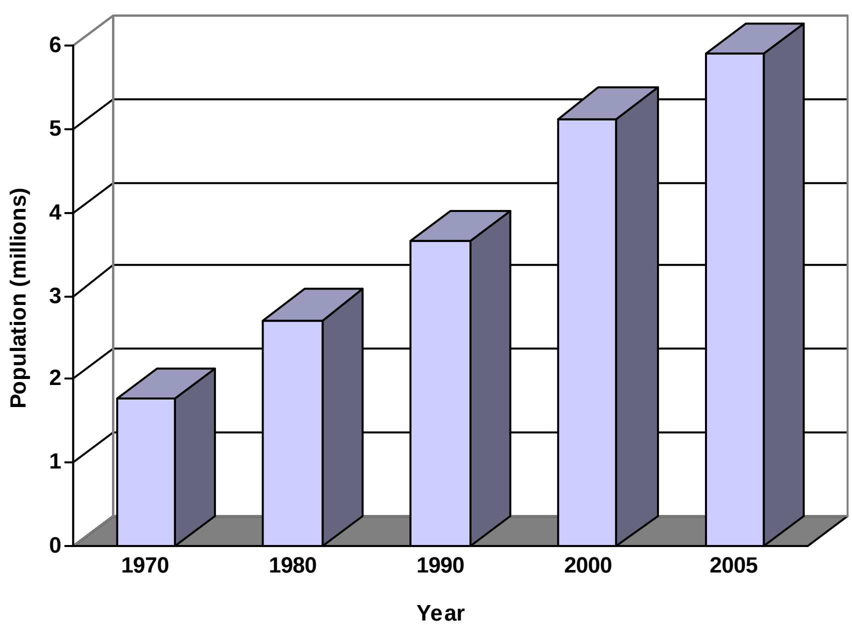
In 2000, evaporative losses from Lakes Powell, Mead, Mohave and Havasu were estimated to total another 1,993,000 acre-feet.

Artificial recharge is water that is recharged to the aquifer through recharge projects, which may be recovered in the future. Incidental recharge is water that percolates to the aquifer after use such as water used for irrigation of farmland or turf facilities, effluent discharge to water courses and septic tank losses. The amount of incidental recharge is affected to a large extent by population, the population not served by a centralized wastewater treatment facility, irrigation efficiency and the method of effluent discharge.

Population

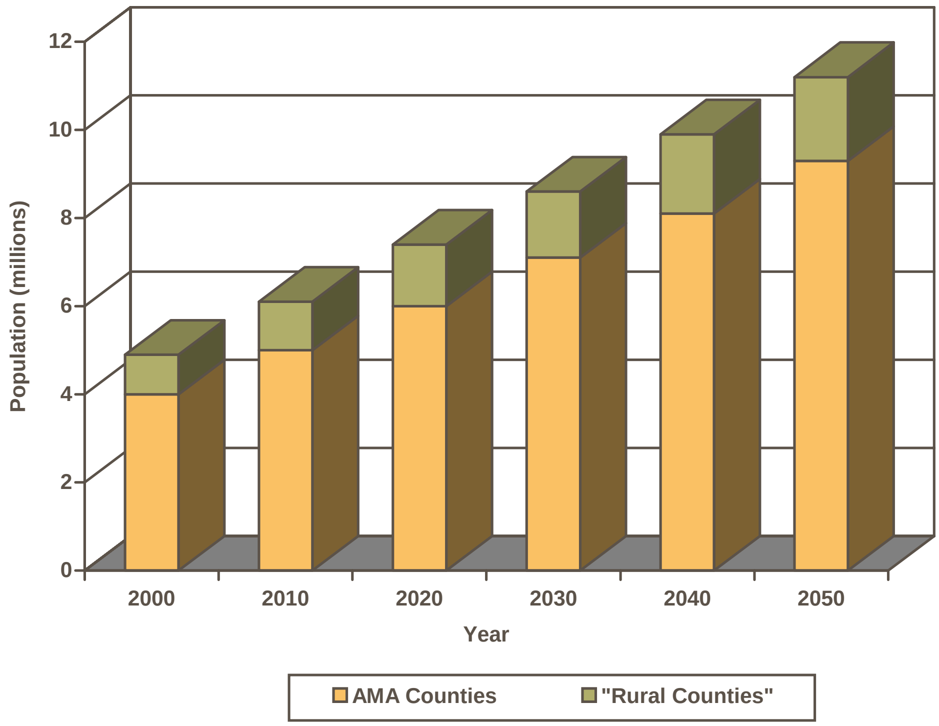
Arizona continues to rank as the nation's second fastest growing state, growing at a rate of about 3% per year. Growth from 1970 to 2005 is shown in Figure 1-13. Arizona grew by about 1 million residents a decade between 1970 and 1990, and then grew from 3.6 million to 5.1 million inhabitants, a 40% increase, in the decade from 1990 to 2000. By July 2005, another 800,000 people moved to Arizona, a 15.8% increase since the 2000 census (Arizona Workplace Informer, 2006).

Figure 1-13 Arizona population 1970-2005



Some rural Arizona counties are currently growing at rates comparable to that of Maricopa County, which contains the rapidly growing Phoenix metropolitan area. Mohave County was the fastest growing county in Arizona between 1990 and 2000 with a 65.8% increase (Arizona Workforce Informer, 2006). Between 2000 and 2005, Mohave, Yavapai and Yuma Counties experienced more than an 18% population growth. Arizona Department of Economic Security projections indicate that by 2050 an additional 1 million people will live in rural Arizona counties and an additional 5 million people will live in AMA counties as shown in Figure 1-14.

Figure 1-14 Projected population growth in Arizona 2000-2050



(www.workforce.az.gov/admin/uploadedPublications/526_coproj97)

Rapid population growth and drought are having significant impacts on water supplies and infrastructure in some areas. Figure 1-15 and Table 1-4 show Arizona communities with population growth greater than 2% per year and 5% per year between the 1990 and 2000 Censuses. The highest growth rates and greatest concentration of high growth rate communities are located in the AMAs, particularly in smaller communities near larger cities. It should be noted that some high growth rates may be due in part to annexation of unincorporated land with its associated population. This is the case with the town of Marana in the Tucson AMA. Although some incorporated cities, such as Sierra Vista and Safford, did not experience more than a 2% annual growth rate between the censuses, unincorporated areas adjacent to them grew rapidly.

Figure 1 - 15
High Growth Rate Communities
in Planning Areas and Groundwater Basins

Table 1-4 Communities with average annual growth rates > 2%.

Planning Area/ Community	Average Annual Growth Rate	1990 Census	2000 Census	Projected 2050 Pop. (DES)
ACTIVE MANAGEMENT AREAS				
Marana	57.3%	2,187	14,718	124,232
Oro Valley	32.3%	6,670	28,190	79,607
Tucson Estates	26.6%	2,662	9,755	NA
Gilbert	23.5%	29,122	97,535	339,556
Surprise	19.4%	7,122	20,915	235,977
Prescott Valley	16.3%	8,904	23,390	72,336
Goodyear	15.0%	6,258	15,650	293,050
Three Points	14.2%	2,175	5,273	NA
Picture Rocks	10.2%	4,026	8,139	NA
Fountain Hills	8.5%	10,030	18,545	54,941
Chandler	8.5%	89,862	166,105	322,164
Sun Lakes	8.2%	6,578	11,936	NA
Peoria	8.0%	50,675	91,415	358,317
Buckeye	8.0%	4,436	8,000	438,897
Arizona City	7.6%	1,940	3,420	7,442
Dewey-Humboldt	7.6%	3,640	6,400	18,106
Carefree	7.6%	1,657	2,910	5,448
Avondale	7.5%	16,169	28,280	157,403
Queen Creek	6.7%	2,667	4,455	122,312
Sun City West	6.5%	15,997	26,344	NA
Chino Valley	6.2%	4,837	7,810	18,230
Florence	6.1%	7,321	11,760	13,359
Scottsdale	5.7%	130,075	204,005	374,482
Avra Valley	4.8%	3,403	5,038	NA
Ak-Chin Village	4.6%	353	516	1,011
Catalina	4.4%	4,864	7,025	NA
Cave Creek	4.2%	2,925	4,150	16,615
Glendale	4.2%	147,864	209,300	341,189
Blackwater	3.6%	400	545	989
Mesa	3.4%	288,104	385,440	664,700
Eloy	3.2%	7,211	9,550	13,218
Phoenix	3.1%	983,392	1,289,125	2,567,878
Green Valley	3.1%	13,231	17,283	NA
Prescott	2.9%	26,592	34,366	65,670
Apache Junction	2.5%	18,092	22,621	33,738
CENTRAL HIGHLANDS				
Lake Montezuma (CDP)	6.2 %	1,841	3,344	4,969
Big Park (CDP)	5.7%	3,024	5,245	11,363
Payson	5.0%	8,377	13,620	29,444
Clarkdale	4.8%	2,144	3,422	6,571
Kachina Village (CDP)	4.5%	1,711	2,664	4,397
Cottonwood	4.5%	5,918	9,179	24,109
Camp Verde	4.2%	6,243	9,451	19,300
Cottonwood-Verde Village(CDP)	4.2%	7,037	10,610	10,905
Black Canyon City (CDP)	4.1%	1,811	2,697	4,939
Whiteriver (CDP)	3.3%	3,775	5,220	9,181
Sedona	2.8%	7,720	10,192	19,591
Globe	2.1%	6,062	7,486	9,827
EASTERN PLATEAU				
Lukachukai (CDP)	30.1%	113	1,565	*
Pinon (CDP)	9.8%	468	1,190	*
Teec Nos Pos (CDP)	9.7%	317	799	1,092
Kaibito (CDP)	9.6%	641	1,607	2,269
Heber-Overgaard (CDP)	5.6%	1,581	2,722	2,761

Table 1-4 Communities with average annual growth rates > 2% (cont.)

Planning Area/ Community	Average Annual Growth Rate	1990 Census	2000 Census	Projected 2050 Pop. (DES)
Show Low	4.4%	5,020	7,695	13,353
Pinetop-Lakeside	4.0%	2,422	3,582	6,064
Taylor	2.8%	2,418	3,176	5,565
LOWER COLORADO RIVER				
San Luis	13.8%	4,212	15,322	47,244
Fortuna Foothills (CDP)	10.2%	7,737	20,478	64,043
Quartzite	6.0%	1,876	3,354	7,077
Wellton	5.6%	1,066	1,829	2,377
Yuma	3.5%	56,966	77,515	154,855
Somerton	3.2%	5,282	7,266	16,296
Ajo (CDP)	2.4%	2919	3705	NA
SOUTHEASTERN ARIZONA				
Whetstone (CDP)	6.2%	1,289	2,354	2,548
Swift Trail Junction (CDP Safford)	6.2%	1,203	2,195	6,574
Sierra Vista SE (CDP)	4.5%	9,237	14,348	16,854
Peridot (CDP)	2.8%	957	1,266	3,192
San Carlos (CDP)	2.4%	2,918	3,716	4,220
Safford	2.3%	7,359	9,232	18,776
Benson	2.1%	3,824	4,711	4,806
Tombstone	2.1%	1,220	1,504	1,789
Duncan	2.1%	662	812	1,217
UPPER COLORADO RIVER				
Mohave Valley (CDP)	7.0%	6,962	13,694	22,160
Lake Havasu City	5.6%	24,363	41,938	94,457
Dolan Springs (CDP)	5.5%	1.090	1,867	2,054
Kingman	4.7%	12,722	20,069	38,737
Bullhead City	4.4%	21,951	33,769	71,423
New Kingman/Butler (CDP)	2.4%	11,627	14,810	39,033
WESTERN PLATEAU				
Colorado City	3.2%	2,426	3,334	9,010

CDP=**census designated place -** A geographic entity that serves as the statistical counterpart of an incorporated place for the purpose of presenting census data for an area with a concentration of population, housing, and commercial structures that is identifiable by name, but is not within an incorporated place. (U.S. Census Bureau, www.census.gov)

- Projections less than 2000 census
- NA=not available

The state has limited mechanisms to address the connections between land use, population growth and water supply. A legislative attempt to link growth and water management planning is the Growing Smarter Plus Act of 2000 (Act) which requires that counties with a population greater than 125,000 include planning for water resources in their comprehensive plans. County plans are required to identify known legally and physically available water supplies, estimate future water demand, and describe how demand will be served by currently available supplies or provide a plan to obtain the necessary supplies. All AMA counties, but only two counties entirely outside AMAs (Mohave and Yuma), fit the population criteria The Act also requires that twenty-three communities outside AMAs include a water resources element in their general plans. References to completed plans are listed in Volumes 2-8 of the Atlas. These plans may contain useful information for water resource planning.

1.2.4 Water Management Overview

Water management in Arizona is composed of a complex system of rules and management authorities that differ for each type of water and by area. These are summarized here and described in more detail in Appendices A, D and E.

One of the most fundamental divisions is that laws governing surface water are distinct from those governing groundwater. Surface water is subject to the doctrine of prior appropriation, based on the tenet of "first in time, first in right." Two general stream adjudications are in progress involving the Gila River and Little Colorado River systems to determine the nature, extent and priority of surface water uses and rights.

Rights to groundwater are subject to the beneficial use doctrine. Outside AMAs there is essentially an unlimited ability to withdraw groundwater as long as it is put to reasonable and beneficial use. The only exception is in the three areas designated as Irrigation Non-Expansion Areas, where the irrigation of new agricultural lands is restricted. Within AMAs the ability to withdraw groundwater is subject to a system of rights and permits pursuant to provisions of the Arizona Groundwater Management Act, A.R.S. § 45-401 *et seq*. (Code).

There has been considerable investment in water resource development and planning in many parts of Arizona, particularly within the AMAs, due to the availability of financial resources, major water supplies and restrictions imposed by the Groundwater Code. Outside AMAs, similar resources and mandatory water management provisions do not exist. Nevertheless, a number of non-AMA communities have recognized the need for water resource planning and have had sufficient resources to develop renewable water supplies, conservation programs and water management plans. Legislation passed in 2005 requires development of water system plans by community water systems state-wide beginning in 2007.

Statewide Water Resources Management Programs

The Code was adopted in 1980 to settle disputes among groundwater users, to secure federal funding for the Central Arizona Project (CAP), and to mitigate severe overdraft conditions in several parts of the state. The Code created three levels of management: AMAs, irrigation non-expansion areas (INAs) and statewide provisions. The AMAs have the highest degree of groundwater management controls. Within AMAs the Code established management goals for each AMA, a system of groundwater rights, a data collection system, well spacing rules, mandatory conservation requirements, and 100-year assured water supply requirements for new developments. INAs were established in certain rural farming areas where the groundwater overdraft was less severe. The management objective in INAs is to protect existing water uses and prevent further declines in groundwater supplies through prohibition of new irrigation acreage. In INAs, larger water users are required to report use. Statewide, the Department licenses well drillers, issues Notices of Intent to Drill for well drilling and regulates well construction. There are also statewide provisions for groundwater transportation. An overview of Arizona water law is found in Appendix A.

Groundwater cannot be transported between groundwater basins outside AMAs or from a groundwater basin outside an AMA into an AMA, except for specific transfers as specified in statute. A.R.S. §§ 45-544 and 45-551. These statutes are designed to protect hydrologically distinct sources of groundwater supplies and the economies in rural areas by ensuring the groundwater is not depleted in one groundwater basin to benefit another.

Within AMAs mandatory water metering and reporting requirements for groundwater rightholders has resulted in the systematic collection of water use data, which is compiled in AMA management plans. A series of 5 consecutive management plans are statutorily required for each AMA (A.R.S.§§ 45-564 through 568). The management plans contain conservation requirements for the agricultural, municipal and industrial water use sectors, as well as water use data, and provide the framework for the day-to-day implementation of Code mandates and Department policies for each AMA.

The Code also contains provisions that address water supplies for subdivided lands. Within AMAs new subdivisions are subject to Assured Water Supply (AWS) provisions. (A.R.S. §§ 45-576 *et seq*.) The Code and the associated AWS Rules adopted by the Department prohibit the sale or lease of subdivided land without demonstration of a 100-year assured water supply. The water use must also be consistent with the management goal of the AMA, which requires use of renewable (non-groundwater) supplies or replenishment of groundwater use. Local governments cannot approve a subdivision plat and the Arizona Department of Real Estate cannot issue a public report for the sale of lots without an AWS determination. Volume 8 contains information on assured water supply determinations for the AMAs.

Outside AMAs, A.R.S.§ 45-108 requires subdivision developers to obtain a determination from the Department regarding the availability of water supplies unless the subdivision will be served by a municipal provider that has been designated as having an adequate water supply. Developers must either obtain a Water Adequacy Report that demonstrates that sufficient water of adequate quality is available for at least 100 years or disclose any "inadequate" determination in the public report and all promotional materials. The ability to market lots without demonstrating an adequate water supply is an issue in a number of rural areas, where local governments may have limited authority to restrict development of subdivisions that may lack sufficient water supplies. Volumes 2-7 contain information on water adequacy and inadequacy determinations for each groundwater basin.

Community Water System Planning

In 2005, the Arizona Legislature passed House Bill 2277, which expands water use reporting an planning statewide. Although the legislation was developed in response to a recommendation by the Governor's Drought Task Force (see Section 1.2.5), it contains the broader objective of improving water management planning at the state and local levels. The legislation requires all community water systems to submit a Water System Plan that includes a Water Supply Plan, a Drought Preparedness Plan and a Water Conservation Plan. It also requires all community water systems to submit an annual report of water withdrawals, diversions and deliveries. Community water system is defined as a public water system that serves at least 15 service connections used by year-round residents or that regularly serves at least 25 year-round residents. A.R.S. § 45-341

The Water Supply Plan must describe the community water system's sources of water, service area, transmission system facilities, monthly system production data, historic demand for the past five years and projected demands for the next five, ten and twenty years. A.R.S. § 45-342(H). The Drought Preparedness Plan must include drought and emergency response strategies, a plan of action to respond to water shortage conditions and provisions to inform and educate the public. A.R.S. § 45-342(I). The Water Conservation Plan may include a variety of measures to reduce water demand. Large water systems (serving more than 1,850 people) must submit plans to the Department by January 1, 2007 and small community water systems by January 1, 2008. Extensions of the deadline and exemptions from the Water Conservation Plan may be granted. Submittal of joint plans is allowed and updates to plans are required every five years. Providers with an AWS are exempt from submitting a Water Supply Plan. The Director is required to provide a water plan form to small providers and to develop a guidance document to assist in the preparation of the Water System Plan.

1.2.5 Water Planning and Water Resource Investigations

Statewide Reports

Prior to publication of the Atlas, the only Department document that provided a broad overview of water supply and demand conditions as well as an analysis of water resource management issues statewide was the *Arizona Water Resources Assessment, 1994 (Assessment)*. The *Assessment* is composed of two Volumes: *Volume I; Inventory and Analysis* and *Volume II; Hydrologic Summary*. The *Assessment* discusses statewide water issues and water supply, demand and management issues for six planning areas, including the AMAs. The Atlas partially retains the purpose and content of the *Assessment*. The Atlas includes more groundwater basin information than the *Assessment.* The description of basins and planning areas is shortened to allow the presentation of more data and maps. The Atlas contains less information about water law, policies and programs than the *Assessment*.

The 1994 *Assessment* was built upon the *State Water Plan* prepared by the Arizona Water Commission, the predecessor to the Department. The *State Water Plan* was published in three phases from 1975 to 1978 and was intended to provide necessary water resource information for water management decision-making. The three phases included: *Phase I, Inventory of Resource and Uses; Phase II, Alternative Futures;* and *Phase III-Part 1, Water Conservation*. Other Phase III reports were envisioned but not produced. The Plan pre-dates the formation of the AMAs and presented information on a state and county basis.

Active Management Area Management Plans

To help achieve the water management goal of each AMA, the Groundwater Code directs the Department to develop and implement water conservation requirements for the agricultural, municipal and industrial water use sectors in five consecutive management periods (1980-2025). The Code generally requires that each consecutive management plan contain more rigorous water conservation requirements. These requirements are published in separate management plans for each AMA (A.R.S. §§ 45-564 through 45-568). In addition to conservation requirements, the management plans contain a water quality assessment and management program, an augmentation and recharge program and conservation assistance programs. Management plans contain water demand information and data and provide the framework for implementation of Code mandates and Department policies (see Appendix A).

Rural Watershed Initiative Program

The Department has provided technical and financial assistance to non-AMA watershed partnerships since the late 1990's through its Rural Watershed Initiative Program. In 1999, the Rural Watershed Initiative (Initiative) received an appropriation of $1.2 million from the Legislature to assist the groups with development of information to support water resources planning in their areas. Although funding has diminished since then, matching funds from other entities have sustained key projects partially funded by the Initiative. A key component of the Initiative approach is that it helps local citizens find solutions that match the specific problems in their own regions. Seventeen watershed groups have formed to conduct water resource studies and evaluate management options (Figure 1-16).

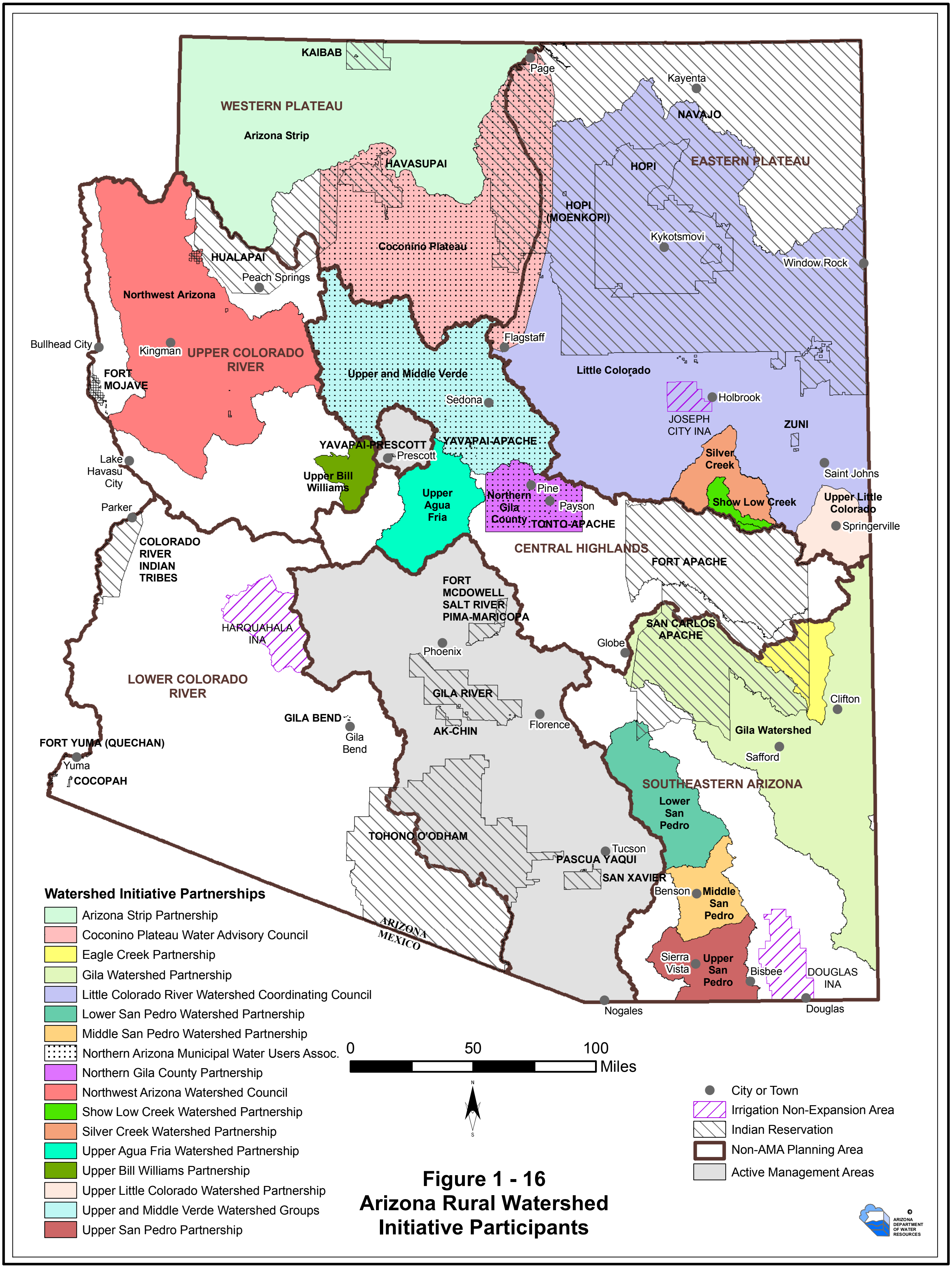


Figure 1 - 16
Arizona Rural Watershed Initiative Participants

Several of the watershed groups were already in place as part of a water quality planning effort by the Arizona Department of Environmental Quality (ADEQ).

The watershed groups vary substantially in terms of resources, staff support, and accomplishments. Of the 17 watershed groups, 15 are actively working on regional solutions to water problems with the goal of developing a comprehensive water resource management plan for their region. In some areas, especially those with significant resources such as the Upper and Middle Verde and the Upper San Pedro, efforts have already produced results in the form of completed and on-going studies, plans, and specific activities to address availability of water. Because of the lack of technical and financial resources and the limited availability of hydrologic data, efforts in other areas may take longer to produce tangible results. Studies and other information associated with these groups have been incorporated into the Atlas and a summary of participants, issues and projects is provided in Appendix B.

Statewide Water Advisory Group

A Statewide Water Advisory Group was formed in April, 2006 to address issues and identify mechanisms, including legislation necessary to encourage and support local initiatives for planning, financing, developing and managing water supplies in non-AMA groundwater basins. At the time of publication of this volume, the process is in its early stages, with the objective of a proposal drafted for introduction during the 2007 Legislative session.

Arizona Drought Preparedness Plan

Governor Napolitano signed Executive Order 2003-12 on March 20, 2003 to address the impact of prolonged drought conditions that began in 1998. The Executive Order established the Governor's Drought Task Force (Task Force) to develop a drought plan for Arizona. The Task Force adopted a mission statement to develop a sustainable drought planning and response process for Arizona that includes:

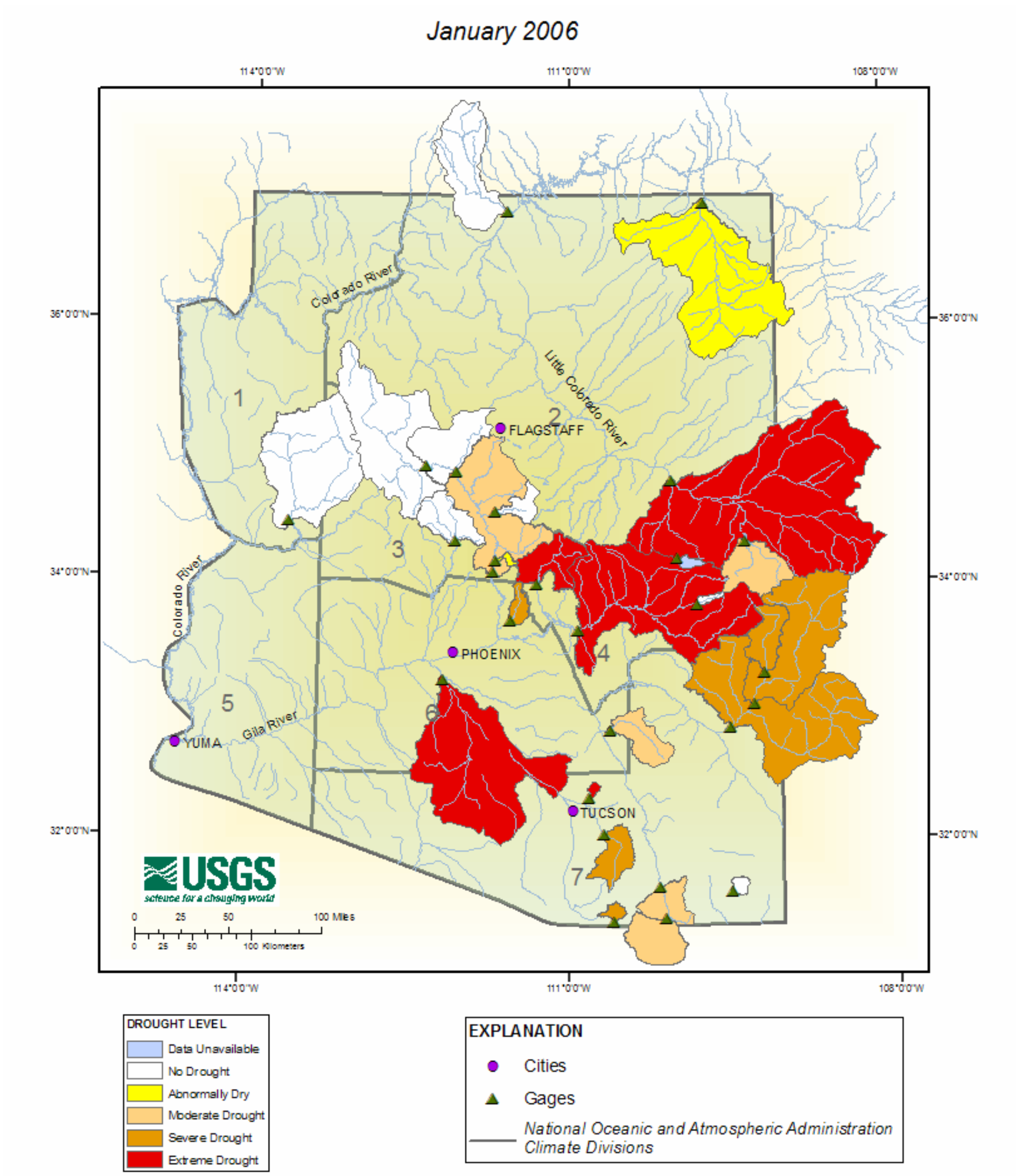
- Timely and reliable monitoring of drought and water supply conditions in the state and an assessment of potential impacts;
- A vulnerability assessment of key sectors, regions, and population groups in the state and possible actions to mitigate potential impacts; and
- Assistance to stakeholders in preparing for and responding to drought impacts, including development of a statewide water conservation strategy and public awareness program. (GDTF, 2004b).

The Task Force adopted the *Arizona Drought Preparedness Plan* in October 2004, and it established a process to allow for ongoing drought monitoring, planning and response. Arizona's drought planning process includes the following three components: a Potable Water Plan to be implemented during emergency short-term drought conditions; the Drought Preparedness Plan, which is the long-term drought mitigation plan with the Operational Drought Plan as its response component; and a Statewide Water Conservation Strategy that is intended to support drought preparedness and promote a water conservation ethic statewide regardless of drought status.

The Task Force adopted a Potable Water Plan for the summers of 2003 and 2004 to address the potential for drought-induced potable water supply shortages. The Potable Water Plan addresses short-term water supply needs for political subdivisions under emergency conditions where there is a risk to public health and welfare. It is intended to monitor, assess and respond to immediate problems and directs at-risk water providers to the appropriate response mechanism. In both years, emergency legislation was passed to allow for the transportation of groundwater across groundwater basins, under specific conditions, to address drought emergencies.

The Drought Preparedness Plan focuses on the need for drought planning by rural communities that often have fewer water supply options during times of drought. Ongoing drought monitoring is critical to the planning process and a Monitoring Technical Committee meets regularly for this purpose. The Monitoring Technical Committee tracks climate changes, forecasts likely future conditions, and determines drought status. One of the Monitoring Committee's efforts has been to better understand how historic droughts have varied spatially and temporally by evaluating historic stream gage data within selected watersheds. Maps similar to Figure 1-17 are created to show drought levels in selected watersheds. Drought levels were identified in the Operational Drought Plan as shown in Table 1-6. Drought indicator data, which could be inches of precipitation, cubic feet per second of stream flow, etc. are expressed as percentiles to allow for comparative analysis. A percentile is a value below which a given percentage of the observations lie. For example, if the observed value for a particular indicator is greater than the lowest 40% of observations during a particular period of record, the drought level is "0", or no drought. The committee will continue to evaluate the results of this effort for applicability for drought prediction and monitoring purposes.

Figure 1-17 Drought levels based on monthly streamflow discharge, January 2006.



Source: Arizona Department of Water Resources, February Drought Monitor Report, 2006.

The Monitoring Technical Committee produces monthly reports, posted on the Department's website (www.azwater.gov). These reports provide an overview of drought conditions in Arizona that include: short-term and long-term drought condition maps; an assessment of reservoir storage; a climate assessment including temperature, precipitation and vegetation status; streamflow and runoff conditions; streamflow forecasts; water conservation tips; and climate and drought forecasts.

Table 1-5 Drought levels based on indicator percentiles.

LEVEL	DESCRIPTION	PERCENTILE
0	No Drought	40.01-100.0%
1	Abnormally Dry	25.01-40.00%
2	Moderate Drought	15.01-25.00%
3	Severe Drought	5.01-15.00%
4	Extreme Drought	0.00-5.00%

Source: Historical Drought Levels of 27 Selected Watersheds in Arizona, USGS, Digital Data Series DDS-62-1, 2005.

The *Arizona Drought Preparedness Plan* also relies on the participation of Local Area Impact Assessment Groups (LAIAG), organized at the county-level to coordinate drought public awareness and to locally monitor drought conditions, identify local impacts and implement mitigation strategies. The LAIAGs provide important local information to the Monitoring Technical Committee that is used to determine drought stage. Primary participants in the LAIAGs are local governmental entities, landowners, water providers, irrigation districts, non-governmental agencies, tribes, federal land management agencies and others. The Interagency Coordinating Group, composed of state and federal entities, advises the Governor of changes in drought status and provides recommendations for improving monitoring, implementation and response.

The Statewide Conservation Program serves two primary functions: to support drought response and to create a water conservation ethic statewide. The statewide effort is intended to expand the reach of existing programs, create new conservation tools for rural communities, promote water education, create guidelines for efficient water use and provide funding and program implementation guidance. In the near-term, the Department's Conservation Office is focusing on technology transfer, education and assistance. Assistance will include help with conservation planning outside AMAs.

The Drought Task Force recommended that the Governor seek legislative authority for the Department to require that all potable water systems develop a drought plan that would identify response options and drought mitigation strategies to reduce drought vulnerability. The Task Force also recommended that the Legislature authorize the Department to require that municipal water systems annually submit water supply information.

In response, the Arizona Legislature passed House Bill 2277 in 2005, which requires community water systems to develop and submit a water system plan to the Department. The plans are intended to improve water management planning, including drought preparedness, at the state and local levels. Certain regulated systems within AMAs are exempt from some of the plan requirements because those requirements would be redundant, such as the annual water use report already required by the Code. The legislation requires water resource planning and statewide water use reporting in a consistent manner, which will identify data gaps and provide information to help the State better identify and respond to water system needs (see also Section 1.2.4). Detailed information on the Arizona Drought Preparedness Plan and House Bill 2277 requirements can be found at www.azwater.gov.

Rural Questionnaires

In March 2003, the Department sent a questionnaire to over 600 rural water providers, jurisdictions (cities and towns), counties and tribal governments in order to gather information on drought impacts in support of preparation of the Arizona Drought Preparedness Plan. Further, it was hoped that information could be gathered about water supply, water use, issues and needs in rural Arizona. The cover letter that accompanied the questionnaire was signed by a number of governmental leaders including the Governor, the President of the Senate and the Speaker of the House. A total of 177 responses were returned, which is considered a very good response rate. Results from the survey were published in October 2004. (ADWR, 2004; www.azwater.gov.)

The 2003 Questionnaire was extensive and included 3 different questionnaires, each tailored to the category of respondent: Water Provider, Jurisdiction and County/Tribal. The questions asked are summarized below for each set of questionnaires.

Water Provider Questionnaire

Water demand

- Number of current and past domestic connections and current population
- Amount of water served to any non-residential customers, by type
- Amount of water used by source
- Whether zoning requirements or homeowners association restrictions result in increased water use

Wells and measurement

- Whether wells and delivery connections are metered
- Number and status of wells (active/inactive)

Growth/Expansion

- Expansion potential of water company and of any others in area
- Projected new large customers

Domestic Wells

- Whether a large number of domestic wells exist in the service area and whether they create problems

Sewer v. Septic

- The percentage of the units in the service area served by a centralized wastewater system

Water-related Issues

- Rank a list of issues including storage, pumping capacity, water levels in wells, need for additional supplies, aging infrastructure, water quality, water rates, drought, etc.

Water Rates

- Rate structure and volume of the average monthly domestic bill in summer and winter

Water Conservation program

- Type of conservation program present and what type of assistance would be most valuable

Drought

- Drought impacts, whether a drought plan is in place and what type of drought assistance would be useful

Water management

- Suggestions for improving water management

Jurisdiction Questionnaire
Water providers • Types of providers serving the jurisdiction and which are most likely to expand to serve new customers *Water Demand* • Estimated percentage of type of water delivered and population within jurisdiction • New non-residential users proposed • Whether domestic wells are a significant source of water *Land Use/Water Use* • Whether lot splitting is a significant concern and if it posed a water supply problem • Whether zoning or homeowners association restrictions result in increased water use *Sewer v. Septic* • The percentage of the units in the service area served by a centralized wastewater system *Water-related Issues* • Rank a list of issues including storage, pumping capacity, water levels in wells, need for additional supplies, aging infrastructure, water quality, water rates, drought, etc. *Water Conservation program* • Type of conservation program present and what type of assistance would be most valuable Drought • Drought impacts, whether a drought plan is in place and what type of drought assistance would be useful *Plans/Management* • Existence of a water supply plan or water resources element, or a drought plan • Impression of Growing Smarter program • Suggestions to improve water management
County and Tribal Questionnaire
Planning • Existence of a water supply plan or water resources element in county plan • Evaluation of current planning process for water planning perspective • Existence of a water element in comprehensive plan if not required • Impression of Growing Smarter program *Land Use/Water Use* • Identification of lands without adequate water supplies for current users • Any proposed new large developments or large commercial/industrial facilities planned and category of use • Whether lot splitting is an issue *Water-related Issues* • Rank a list of issues including storage, pumping capacity, water levels in wells, need for additional supplies, aging infrastructure, water quality, water rates, drought, etc. *Legislation/Assistance* • What legislation or state assistance would be of greatest benefit to ensure future water supplies *Water Conservation program* • Type of conservation program present and what type of assistance would be most valuable *Drought* • Drought impacts, whether a drought plan is in place and what type of drought assistance would be useful

The 2003 Questionnaire Report contains detailed results for the three categories of respondents. The results from the water-related issues section for water providers and jurisdictions is shown in Table 1-7 for each planning area. As shown, infrastructure problems appear to be widespread and include aging infrastructure in need of replacement, inadequate sources of capital to pay for infrastructure improvements, and lack of central wastewater treatment and collection systems. Water supply problems were also widely reported in the Eastern Plateau, and Upper and Lower Colorado River Planning Areas. Respondents in the Central Highlands and Lower Colorado River Planning Areas reported water quality issues: primarily the ability to meet the arsenic standard set by EPA and concern about the proximity of wells to sources of contamination. Although drought was not a major concern for the majority of water providers and jurisdictions, at least one drought impact was reported by the majority of respondents in the Southeastern Arizona, Central Highlands and Eastern Plateau Planning Areas. (Because there was only one respondent from the Western Plateau, issues were not identified.)

Although the questionnaires were tailored to the three different groups of respondents, there were some common questions. Growth was anticipated by most respondents, but few expected that growth would include large users such as industrial facilities or prisons. Relatively few respondents in any category had a water conservation program and of those that did, most programs consisted of water conservation materials. This likely reflects a lack of resources for anything more extensive, because many respondents mentioned the desire to expand their program.

Table 1-6 2003 Rural Questionnaire issues identification by planning area (from Rural Water Resources 2003 Questionnaire Report).

	PLANNING AREA					
	Central Highlands	Eastern Plateau	Lower Colorado River	South-eastern Arizona	Upper Colorado River	Western Plateau
Number of Water Provider and Jurisdiction Respondents	46	37	27	29	18	1
Number of Water Provider and Jurisdiction Respondents that Ranked Issues	24	23	17	14	11	
ISSUES						
Infrastructure	X	X	X	X	X	
Water Supply		X	X		X	
Water Quality	X		X			
DROUGHT IMPACT						
Majority of Respondents Noted a Drought Impact	X	X		X		

Half of the jurisdictions, two-thirds of the counties, all the tribes and forty percent of the water providers that responded mentioned that they had been affected by the drought but very few reported having a drought plan. While priority issues varied between groups, four were mentioned consistently among the top three: the need for additional water supplies for future needs, lowering water tables, aging infrastructure, and inadequate sources of capital to pay for infrastructure improvements. Interestingly, while many respondents reported that domestic wells were a significant source of water for households in their area, few mentioned that they caused any water supply problems.

To support this initial information gathering effort and to collect additional information to include in the Atlas, the Department conducted a second, brief, direct-contact survey in 2004, focused on 360 rural water providers. Because of the direct contact effort, some level of response was received from 246 water providers, a 65% response rate. The 2004 survey lacked the drought and growth impact focus of the 2003 survey but included questions about water demand and supply, water-level trends, the degree of metering, water quality and issues.

The highest priority issue identified from this survey was the lack of capital for infrastructure repair. This mirrors the 2003 questionnaire results. Other priority issues were drought, inadequate supplies for the future, meeting the arsenic standard and infrastructure problems.

Table 1-8 shows a summary of results from the 2004 survey. The issues list is not identical to the 2003 survey and the rating system was different. Respondents were asked to rank issues on a scale of 0-3 with "3" representing a major concern, "2" a moderate concern, "1" a minor concern and "0" no concern. Similar to the 2003 report, issues have been compressed into categories. The infrastructure category includes infrastructure in need of replacement and inadequate capital to pay for infrastructure improvements. The water supply category includes inadequate supply for either current or future demand. The storage and capacity category includes inadequate storage capacity to meet peak demand and inadequate well capacity to meet peak demand. With the exception of drought impact (because there was only one question compared to two each for the other issue categories), an "X" indicates that a majority of respondents identified an issue as a major or moderate concern. More detail from both the 2003 and 2004 surveys is provided in the planning area volumes.

Table 1-7 2004 Rural Questionnaire issues identification by planning area.

	PLANNING AREA					
	Central Highlands	Eastern Plateau	Lower Colorado River	South-eastern Arizona	Upper Colorado River	Western Plateau
Number of Water Provider Respondents	71	44	14	56	30	10
Number of Water Provider Respondents that Ranked Issues	66	39	14	46	23	10
ISSUES						
Infrastructure	X	X	X	X	X	
Water Supply	X		X	X	X	X
Storage/Capacity		X	X	X	X	
Majority of Respondents Noted a Drought Impact	X			X	X	

Arizona Department of Water Resources Studies, Reports and Activities

The Department collects surface water and groundwater data statewide and produces technical documents, reports and special studies of critical areas. The Department's Hydrology Division provides data, technical assistance and hydrologic reviews to all divisions of the Department and to local water users, state agencies and the federal government. This hydrologic information is often organized by groundwater basin or by AMA. The Department cooperates with the United States Geological Survey (USGS) on production of USGS Water Withdrawals Reports. The report *"Water Withdrawals for Irrigation, Municipal, Mining, Thermoelectric-Power, and Drainage Uses in Arizona Outside of Active Management Areas, 1991-2000"* (Scientific Investigations Report 2004-5293), with unpublished updates, was used for the water demand estimates in the Atlas in most cases.

The Groundwater Modeling Section of the Department's Hydrology Division develops numerical groundwater flow models for various areas in the state. Models for the Phoenix, Pinal and Prescott and Tucson AMAs have been completed and a model for the Santa Cruz AMA is nearing completion. Outside the AMAs, the Department has developed a Yuma area model to test the effect of increased drainage well pumpage and lining of irrigation canals on high water-table levels in urbanized sections of the Yuma Valley. This model was provided to the U.S. Bureau of Reclamation, which operates and maintains it. The Department also developed a groundwater flow model of the Sierra Vista subwatershed of the Upper San Pedro Basin and used it to simulate several different potential growth patterns and potential effects on surface water flows *(ADWR Modeling Report No.10 and Supplement, 1996).*

The Department's Basic Data Unit annually collects groundwater level measurements from approximately 4,000 wells statewide. Of these, there are approximately 2,000 "index wells". Hundreds of water quality samples are also collected annually as funding allows. The Unit develops Hydrologic Map Series (HMS) Reports that show groundwater conditions by basin. To date the Department has produced 34 HMS reports, 27 of which are of areas outside the AMAs. The Department has also produced six hydrologic monitoring reports: two for the Phoenix AMA, three for the Prescott AMA and one for the Santa Cruz AMA. These reports are available from the Department. Groundwater data are stored in the Department's ORACLE Groundwater Site Inventory database (GWSI). GWSI is a field-verified database consisting of thousands of wells including locations, current and historic water-level information, discharge and field water quality data. This database is available from the Department on CD in a Microsoft Access version.

The Department's Basic Data Unit has also begun using automated groundwater data collection devices in the past few years. The continuous record of water-levels allows data users to monitor the hydrologic behavior of groundwater systems more completely and to assess changes more accurately. They also allow changes in aquifer storage capacity to be tracked on a frequent basis and to better relate changes in water levels to groundwater pumpage and riparian demand. A primary purpose of the automated sites is to collect additional data in areas subject to rapid change, such as high growth areas or areas that are sensitive to change. Monitoring sites are also selected to characterize large geographic areas and general aquifer conditions. There are plans to make the transducer data continuously available through the Department's website. The Department and the USGS operated 52 automatic water-level recording sites outside AMAs in 2005 shown on Figure 1-18. There are plans to add additional sites, if funding permits, in areas where hydrologic data are needed. Flagstaff, Williams, Vidler Water Company (Harquahala Basin) and Tucson Electric Power Company (Little Colorado River Plateau Basin) operate an additional 29 recording sites. A map of automatic water-level recording sites in AMAs is provided in Volume 8.

The Department's Geophysics/Surveying Unit gathers, processes and interprets land subsidence and aquifer storage data and supports other departmental programs as needed. The data consist primarily of Global Positioning System (GPS) positions and elevations at discrete points, absolute and relative gravity values at discrete points and Synthetic Aperture Radar satellite data that cover several critical areas of the State. Much of the unit's activities have been conducted within the State's AMAs, primarily for subsidence monitoring. The unit has also mapped depth to bedrock in the Hassayampa subbasin of the Phoenix AMA. However, the unit has also performed GPS measurements at rural WQARF sites and, in 2006 began conducting gravity surveys in several groundwater basins in the Upper Colorado River Planning Area in support of a hydrologic investigation of rural watersheds effort in cooperation with the USGS. Micro-gravity measurements can yield data on aquifer storage capacity.

The Water Quality Assurance Revolving Fund (WQARF) was created under the Environmental Quality Act of 1986 to support hazardous substance cleanup efforts in the state. The Department's WQARF Technical Support Unit provides hydrologic support and technical review of many water quality-related activities that involve the Department. The WQARF unit has published site-specific well construction and abandonment procedures for areas in Yuma and for the Pinal Creek WQARF site. Additional areas of water quality concern have been identified for special well construction standards including portions of the town of Quartzite.

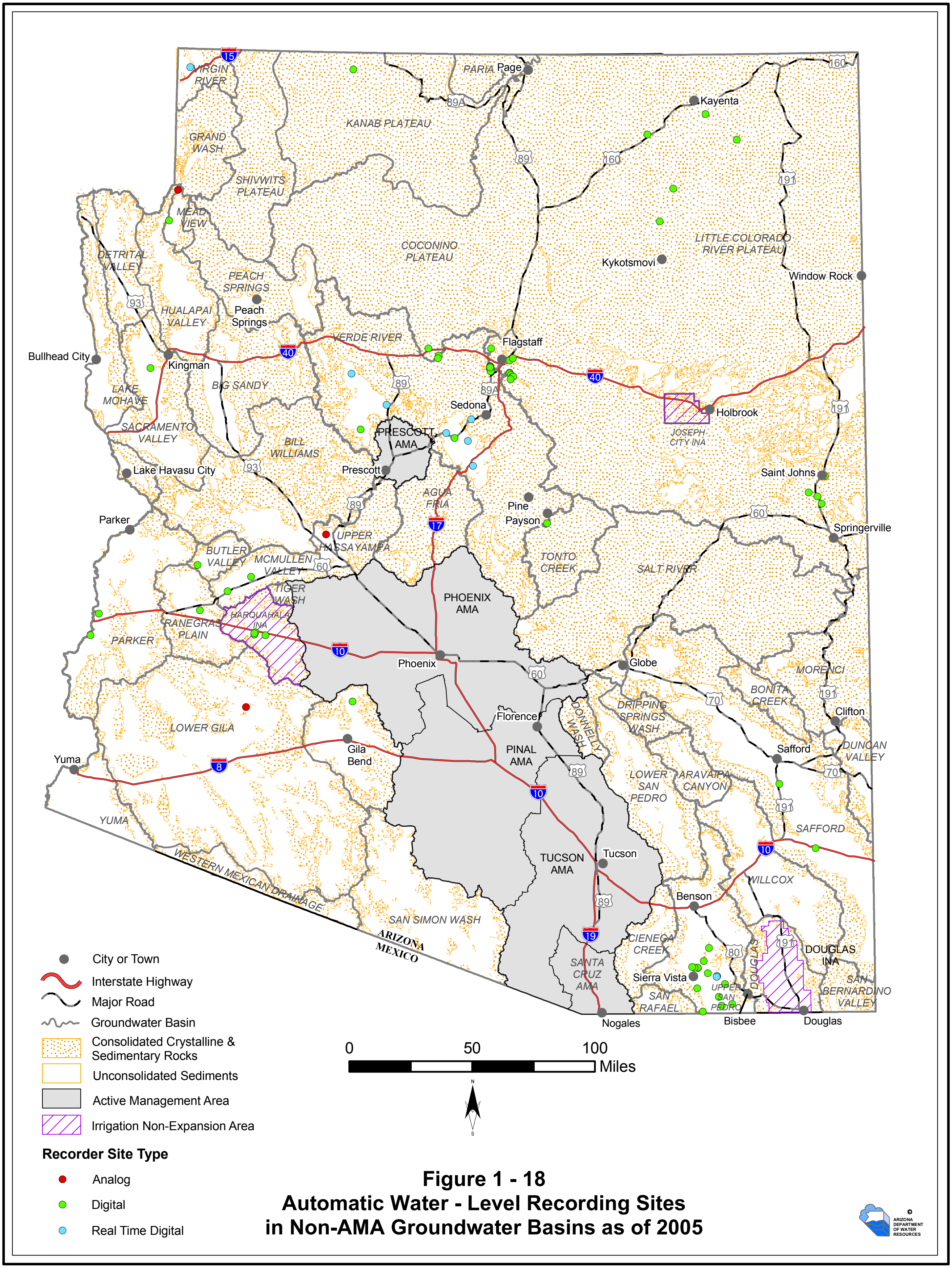


Figure 1 - 18
Automatic Water - Level Recording Sites in Non-AMA Groundwater Basins as of 2005

The Department's Dam Safety and Flood Mitigation Division is responsible for the safety of all non-federal dams in Arizona. It conducts field investigations to evaluate whether safety deficiencies exist and to develop action plans to remove deficiencies. The Division also reviews applications for proposed dams and monitors new dam construction and the repair of existing dams to reduce the likelihood of catastrophic dam failure. The Flood Mitigation Section participates in flood mitigation programs, administers the Community Assistance Program, assists in delineating floodplains and developing flood control projects, sets state standards for floodplain management and coordinates the planning, design, and construction of flood warning systems. The Section works closely with other state and local entities to administer the National Floodplain Insurance Program and to augment the statewide flood-warning network. Data on non-federal dams and on flood warning system gages for non-AMA groundwater basins are presented in Volumes 2-7 and for AMAs in Volume 8.

The Department staffs the Arizona Water Protection Fund (AWPF), administered by a fifteen member Commission. The AWPF was established to provide funding to support projects that enhance and restore rivers, streams and riparian habitats in Arizona. A number of AWPF Grants have been disbursed to fund projects in rural Arizona. A description of the AWPF including a list of grants and a map showing the location of projects by planning area is found in Appendix C.

Notable Department studies conducted outside AMAs include:

- Numerous Hydrologic Map Series Reports (1980-present)
- Numerical Model and Scenario Simulations of the Yuma Area Groundwater Flow Model Arizona, California, and Mexico: in Cooperation with the Yuma County Flood Control District (1993).
- Arizona Water Resources Assessment (1994).
- The Arizona Riparian Protection Program Legislative Report (1994).
- Groundwater Flow Model of the Sierra Vista Subwatershed and Model Scenarios of Future Groundwater and Surface Water Conditions of the Upper San Pedro Basin (2 reports, 1996).
- Verde River Watershed Study (2000).
- Upper San Pedro Basin Active Management Area Review Report (2005).

A number of studies have been conducted by the Department within AMAs. These include:

- Numerous Hydrologic Map Series Reports (1980-present).
- First Management Plans (1980-1990) for the Phoenix, Pinal, Prescott, and Tucson AMAs.
- Second Management Plans (1990-2000) for the Phoenix, Pinal, Prescott, and Tucson AMAs.
- Third Management Plans (2000-2010) for the Phoenix, Pinal, Prescott, Santa Cruz and Tucson AMAs.
- Santa Cruz AMA Hydrologic Monitoring Report (1997-2001).
- Prescott AMA Hydrologic Monitoring Reports (2000-2001; 2001-2002; 2002-2003).
- Phoenix AMA Annual Status Reports (Comprehensive Hydrologic Monitoring Plan) (2001-2002; 2002-2003; 2003-2004).
- Numerous groundwater modeling reports for the Pinal, Phoenix, Prescott and Tucson AMAs.

The two general stream adjudications in Arizona are the Gila River System and Source and the Little Colorado River System and Source. The Department provides technical and administrative support to the stream adjudication court and the special master, including investigation of surface water rights claims and preparation of technical reports. By statute, the Department is required to prepare and publish comprehensive Hydrographic Survey Reports (HSRs) for each of the watersheds within the two adjudications. HSRs are multi-volume publications that involve intensive data collection and field inspection efforts including detailed information regarding hydrology and water rights claims. Preliminary, final and supplemental HSRs and other adjudications-related reports are:

- Hydrographic Survey Report for the Silver Creek Watershed, ADWR, November 30, 1990.
- Hydrographic Survey Report for the San Pedro River Watershed, ADWR, November 20, 1991
- Hydrographic Survey Report for the Upper Salt River Watershed, ADWR, Draft December 1992.
- Technical Assessment of the Fort McDowell Indian Community Water Rights Settlement, ADWR, May 1993.
- Little Colorado River Settlement Committee Group "A" – In-Basin Negotiating Committee Inventory of Irrigation, Reservoirs, and Stockponds in the Upper Little Colorado River Watershed, ADWR, July, 1994.
- Little Colorado River Settlement Committee Group "A" – In-Basin Negotiating Committee Inventory of Irrigation and Reservoirs in the Lower Little Colorado River Watershed, ADWR, September 1994.
- Hydrographic Survey Report for Indian Lands in the Little Colorado River System, ADWR, September 1994.
- Hydrographic Survey Report for the Gila River Indian Reservation, ADWR, December 1996
- Technical Assessment of the San Carlos Apache Tribe Water Rights Settlement, ADWR, May 1999.
- Supplemental Contested Case HSR for Phelps Dodge's Claims to Show Low Lake, January 2005.

Federal, Tribal, Local and Other State Agency Roles in Water Management

The role of Indian Nations in water supply and management in Arizona, is becoming increasingly important. With approximately 28% of Arizona land held in Trust by the federal government for the benefit of Native Americans, the determination of Indian water rights and water use by Indian communities have a significant impact on water supplies and water management in the state. Non-AMA areas affected by Indian water rights include the Coconino Plateau Basin, the Little Colorado River Basin, the Lower San Pedro Basin, the Upper Gila River, the Verde River Basin, the Mogollon Rim, Northwestern Arizona south of the Colorado River in the rapidly developing greater Kingman area and in the Yuma and Parker Basins. Indian settlements are also a major factor in water management in the Phoenix, Pinal and Tucson AMAs.

Passage of the Arizona Water Settlements Act of 2004 (P.L. 108-451), the largest settlement in terms of dollars and volume of water in the West, represents a major milestone in providing certainty about water supplies in much of central and parts of southeastern Arizona. The settlement involves 40 parties in six counties and provides 653,500 acre-feet of water to the Gila River Indian Community and 76,000 acre-feet to the Tohono O'odham Nation.

The Act and its side agreements have significant implications for water management and access to water in parts of rural Arizona. These agreements include limits on access to water, restriction of agricultural irrigation to historic acreage, caps on water use that may affect municipal and industrial use, and limits on the number of new wells in certain areas. There is a prohibition against the construction of new large reservoirs in the Upper San Pedro Basin and a blanket waiver from future lawsuits in Cochise County in exchange for no limits on agriculture. While the settlement creates limitations on non-Indians, it does not adjudicate their rights nor does it restrict groundwater use except in designated impact zones. Passage of the law requires substantive changes to state law.

The Fort McDowell Indian Community (FMIC) settlement in 1990 entitles the FMIC to an annual entitlement of 35,950 acre-feet from the Verde River and CAP. Provisions of the settlement allow for 100-year leases of the CAP portion to off-reservation users in Maricopa, Pima, and Pinal and Counties. The City of Phoenix has a lease of 4,300 acre-feet per year.

The San Carlos Apache Tribe Settlement Act of 1992 awarded an annual entitlement to the Tribe of 71,435 acre-feet of water from the Salt River, Gila River, Black River and CAP. The CAP portion may be leased to off-reservation users within Graham, Greenlee, Maricopa, Pima Pinal, and Yavapai, counties. There are a number of parties to the settlement agreement, which includes a 100-year lease for a portion of the Tribe's CAP water with the City of Scottsdale. The water rights claims of the Tribe to the Gila River side of the reservation still need to be resolved.

The water rights claims of the Navajo Nation, the Hopi Tribe, and the San Juan Southern Paiute within the Little Colorado River Plateau (LCR) Basin are still unresolved. These claims involve both the Little Colorado River and the Colorado River. Claims to the Colorado River are complicated by provisions of the Law of the River, which restrict transfers between the Upper Basin and the Lower Basin. Discussions have included proposed pipelines to move water from various sources to areas within the LCR Basin, including partnerships with non-Indian entities. Talks also continue with the San Carlos Apache Tribe regarding uses in the upper Gila River. A complete description of Indian Water Rights settlements is found in Appendix D.

A number of federal agencies have water supply and management authorities in Arizona, in part because 48% of the state is comprised of federal land. Federal agencies and laws are discussed in more detail in Appendix E.. Management of the Colorado River involves a complex array of management authorities, determined over the years by federal laws, court cases, interstate compacts and an international treaty, collectively called "the Law of the River." These laws have resulted in dam construction, apportionment of Colorado River water to the basin states and to Mexico, salinity reduction requirements and other actions that affect water management in Arizona. The Bureau of Reclamation administers the Colorado River reservoirs and contractual arrangements for the use of Colorado River water and is involved with regional planning activities, water conservation programs and water augmentation feasibility studies.

The USGS gages streamflows, conducts scientific analyses of hydrologic resources, and produces reports on Arizona water use by sector and source. The U.S. Forest Service (USFS) develops plans that include watershed management criteria to protect and enhance runoff and holds many surface water rights for various uses. The U.S. Bureau of Land Management (BLM) is a major landowner in the state and has responsibility for some key water management areas such as the San Pedro Riparian National Conservation Area. The U.S. Environmental Protection Agency (EPA) implements national programs that include watershed management, groundwater protection, water quality standards, toxic waste cleanup and border-region environmental programs.

In addition to the Department, other state agencies and authorities influence water management in Arizona. The CAWCD is a multi-county, tax-levying public improvement district of the state, responsible for operating and maintaining the CAP and managing the construction repayment costs to the federal government. The CAWCD Board sets policy, including pricing and delivery scheduling priorities. In recent years, Arizona has utilized its entire allotment of Colorado River water, either by direct use or through storage in underground aquifers.

Many communities in rural Arizona are served by private water companies that are regulated by the Arizona Corporation Commission (ACC). The ACC is a constitutionally formed commission with an elected 5-member board. Among its responsibilities is regulatory authority over private water and private sewer companies. It regulates rates and authorizes curtailment tariffs that allow a utility to request that customers reduce water consumption when the demand is greater than the production.

Private water companies lack many of the water management tools available to public utilities and are generally required to keep cost of service low. However, the ACC is increasingly considering rate increases to allow renewable supply utilization and for modest water conservation programs.

Public water systems have rate-setting and water use ordinance authorities. The larger municipal utilities are more likely than private water companies to have long-range management plans, construct effluent conveyance systems and have the financial resources to implement conservation and other water management programs.

Funding water infrastructure improvements is a major problem in some areas. Community development block grants through the Arizona Department of Commerce and the Greater Arizona Development Authority (GADA) are a source of funding. In addition, the Water Infrastructure Finance Authority (WIFA), an independent state Agency, offers below market interest on loans to finance the construction, rehabilitation and/or improvement of drinking water, wastewater, wastewater reclamation and other water quality facilities and projects.

The Arizona Department of Environmental Quality (ADEQ) has a Water Quality division. Core responsibilities include pollution control, monitoring and assessment, compliance management, cleanups of contaminated soil and water, education, outreach and financial assistance and policy development. Its programs influence water supply planning and operations at the local level. (See Appendix A).

SECTION 1.3 Data Sources and Methods

This section describes the sources of data and methods of analysis for tables and maps presented in Volumes 1-7 of the Atlas. Volume 8, AMA Planning Area, will contain additional information, requiring discussion of supplementary data sources and methods that will be included in that volume. These descriptions may not completely explain some of the details of the data evaluation and analysis in all cases. More detailed information may be obtained by contacting the Department's Statewide Water Conservation and Strategic Planning Division.

1.3.1 Adequacy Determinations

Information related to the Department's water adequacy determinations is presented on basin-scale maps (*Location of Water Adequacy and Inadequacy Determinations)* and summarized in a table for each basin (*Water Adequacy and Inadequacy Determinations)* in Volumes 2-7. The tables include subdivision names, number of lots, location data, Department application numbers, determination dates, reasons for inadequate determinations, and water providers.

Sources for this information come from the Department and include electronic databases maintained by the Office of Assured and Adequate Water Supply and paper files stored in the Hydrology Division. Database queries were reviewed and some information was excluded from the Atlas based on subdivision location, duplicate applications, etc. Paper files were also reviewed to complete information that had not been entered into the databases such as number of lots and reasons for inadequate determinations.

Sources for assured water supply determinations come from the Department and include electronic databases maintained by the Office of Assured and Adequate Water Supply and paper files stored in the Hydrology Division.

Each determination of the adequacy of water supplies available to a subdivision is based on the information available to the Department and the standards of review and policies in effect at the time the determination is made.

1.3.2 Aquifers

Flow Direction

Groundwater flow directions are presented on basin-scale maps (*Groundwater Level Conditions)*. This information was taken from a variety of technical reports prepared by the Department and the USGS. Flow directions are not shown for some basins, either because of insufficient groundwater level data and/or complex subsurface geology. The flow directions that are shown in the Atlas generally reflect long-term, regional aquifer flow in the basin and are not meant to depict temporary or local-scale conditions.

Major Types

Major aquifer types are listed in a table for each basin (*Hydrogeologic Data)* and are generally described in the text for each planning area volume. Information on aquifer types was taken from Volume II of the Department's 1994 *Arizona Water Resources Assessment.* To ensure consistency and simplify comparison between basins, aquifer descriptions from the 1994 *Assessment* were reviewed and grouped in the Atlas into five basic aquifer types:

- Basin fill;
- Igneous and metamorphic rocks;
- Recent stream alluvium;
- Sedimentary rock; and
- Volcanic rock.

In some basins, two or more of these aquifer types are found. Also, several aquifers in Arizona have been given specific names related to their geologic formation or location. Where known and applicable, this information is included in the Atlas. The aquifers in most basins can be further described by their rock type or sediment grade (e.g. sandstone vs. limestone) and position in the geologic sequence (e.g. upper vs. lower basin fill). This level of detail is not provided in the Atlas, but for reference, can be found in the 1994 *Assessment*.

Recharge and Storage

Estimates of aquifer recharge and storage are listed in a table for each basin (*Hydrogeologic Data)*. The estimates are based on one or more of six primary data sources:

- *Phase I; Arizona State Water Plan* published by the Arizona Water Commission in 1975;
- A 1986 study by the USGS of predevelopment hydrologic conditions in the alluvial basins of Arizona and adjacent states;
- A 1990 internal report by the Department summarizing water resources information for the groundwater basins;
- Volume II of the Department's 1994 *Arizona Water Resources Assessment*;

- A 1995 report by the USGS describing groundwater flow models developed for selected alluvial basins in south-central Arizona and parts of adjacent states; and,
- Various hydrologic reports and maps prepared by the USGS and the Department for select basins and subbasins across Arizona.

In many cases, these data sources provide information for areas that do not exactly coincide with the Department's groundwater basins. It was often necessary to adjust reported recharge and storage values to account for these differences in basin area as well as the location of the border between basin fill and bedrock and zones of high recharge (i.e. along or near mountain fronts).

Aquifer recharge is a difficult hydrologic parameter to measure and, on a regional level, it is usually determined indirectly either through development of water budgets and/or use of groundwater flow models. The recharge estimates presented in the Atlas generally represent long-term, natural (predevelopment) conditions. Wet and dry periods are averaged and artificial recharge is not considered. Such factors can significantly affect aquifer recharge in a given year. Aquifer storage is also a difficult parameter to measure and the estimates in the Atlas were usually based on a combination of point data from wells and results from large-scale surface geophysical surveys. Where aquifers consist of consolidated rock and storage is controlled by fractures, storage estimates can be highly unreliable. In light of these uncertainties, the Atlas often provides more than one estimate of aquifer recharge and storage for each basin.

1.3.3 Climate

Average Annual Precipitation

Average annual precipitation, in inches, is shown on basin-scale maps (*Meteorological Stations and Annual Precipitation*). Contour lines and color-coding are used on the maps to delineate areas of equal and similar precipitation. This precipitation information comes from the Spatial Climatic Analysis Service (SCAS) at Oregon State University. Using an analytical tool called PRISM (Parameter-elevation Regressions on Independent Slopes Model), SCAS analyzed regional precipitation data averaged over the period 1961-1990 and prepared digital precipitation maps for the United States in 1998. The Department downloaded the PRISM map for Arizona from the SCAS website.

Evaporation Stations

Evaporation data collected from AZMET and pan stations are summarized in a table for each basin (*Climatic Data*) and station locations are shown on basin-scale maps (*Meteorological Stations and Annual Precipitation*). Arizona Meteorological Network (AZMET) stations are operated in southern and Central Arizona and provide weather-based information to agricultural and horticultural interests. Pan stations refer to Class A evaporation pans that are used to estimate evaporation rates from natural surfaces such as shallow lakes and wet soils. Summary tables in the Atlas list the name and elevation of these stations, their period of record, and average annual evaporation rates in inches. Note that the pan evaporation rates listed are usually adjusted by multiplying by 0.7 or 0.8 before being used to estimate natural conditions. Reference evapotranspiration (Eto) rates are listed for the AZMET stations and refer to the amount of water evaporated and transpired by well-maintained, well-watered turf grass.

Data from the AZMET stations were downloaded from a website maintained by the University of Arizona Cooperative Extension, and data from the pan stations were downloaded from a website maintained by the Western Regional Climate Center (WRCC). Pan data were presented as monthly averages, which the Department summed for all months and presented as an annual average. Some pan stations did not measure evaporation rates during winter months and others estimated those rates using other meteorological data.

Several factors can affect evaporation rates, including air temperature, humidity, and wind. The data presented in the Atlas represent conditions at the measuring stations and provide a general indication of average evaporation rates in the basin. Care should be taken when using these data for site-specific studies.

Precipitation and Temperature Stations

Precipitation and temperature data from a network of weather stations are summarized in a table for each basin (*Climatic Data*) and station locations are shown on basin-scale maps (*Meteorological Stations and Annual Precipitation*). The summary tables list the name and elevation of these stations, their period of record, and temperature and precipitation data. Temperature data include average minimum and maximum temperatures in degrees Fahrenheit and in which months these extremes occur. Precipitation data include average seasonal precipitation and average annual precipitation in inches. Seasons are defined in the Atlas as follows:

- Winter – January through March;
- Spring – April through June;
- Summer – July through September; and
- Fall – October through December.

The weather stations presented are part of a cooperative network maintained by the National Oceanic and Atmospheric Administration (NOAA) and the National Weather Service (NWS). Data from these stations has been compiled by the WRCC and posted on its website. Statistics presented in the summary tables were downloaded directly from this website. Several factors can affect temperature and precipitation rates, particularly elevation and other geographic features. The data presented in the Atlas represent conditions at the measuring stations and provide a general indication of average temperature and precipitation conditions in the basin. Care should be taken when using these data for site-specific studies.

Snowfall Stations

Snowfall data from Snowcourse and Snowpack Telemetry (SNOTEL) stations are summarized in a table for each basin (*Climatic Data*) and station locations are shown on basin-scale maps (*Meteorological Stations and Annual Precipitation*). The summary tables list the name and elevation of these stations, their period of record, and snowpack measurements. The average snowpack at the beginning of each month is presented as inches of snow water content, also referred to as the snow water equivalent. Only those months when snow surveys are usually conducted (January through June) are included.

Snowcourse and SNOTEL stations are operated by the Natural Resources Conservation Service (NRCS). Data from these stations have been compiled by NRCS and posted on its website. Statistics presented in the summary tables were downloaded directly from this website. Many factors can affect snowpack depths such as aspect, elevation and forest cover and NRCS takes great care to locate snow course and SNOTEL stations that provide representative data. Nevertheless, the data presented in the

Atlas represents conditions at the measuring stations and only provides a general indication of average snowfall conditions across the highlands of some basins. Care should be taken when using these data for site-specific studies.

Trends in Precipitation and Temperature

Long-term trends in precipitation and temperature are shown statewide in Section 1.2.2 of this volume, and by planning area in Volumes 2 through 8. Trend data are presented graphically with explanatory text. This information was contributed by researchers at the University of Arizona, including the Institute for the Study of Planet Earth, which is responsible for the Climate Assessment for the Southwest (CLIMAS) program.

1.3.4 Contamination Sites

Contamination sites are shown on planning area maps (*Contamination Sites*). Included are the locations of U.S. Department of Defense (DOD), Voluntary Remediation Program (VRP), Superfund (listed on the National Priorities List or NPL) and WQARF sites as well as leaking underground storage tanks (LUST).

The data provided by ADEQ included locations for all LUST sites in Arizona, regardless of reported contaminant levels or whether remediation had been completed. For purposes of the atlas, LUST sites are only shown where contamination is either suspected or known to exist and remediation is required to meet soil and water quality standards. LUST sites that meet applicable standards and/or have been remediated and closed-out are not included.

1.3.5 Cultural Water Demands

Location of Major Water Use

Locations of major water use are shown on basin-scale maps (*Cultural Water Demands*). Included on the maps are agricultural lands, low- and high-intensity developments, mines and power plants. The primary data source for the water use maps was a land cover study of the southwestern United States, completed by the USGS in 2004. Land cover types were mapped in this study at a 5- to 12-acre resolution using Landsat satellite imagery collected between 1999 and 2001. The Department supplemented the data with the locations of active power plants and mines.

Due to its resolution, use of Landsat imagery to map land cover types requires a high degree of interpretation and some areas of water use, particularly agricultural lands, may be misclassified. The Department reviewed the USGS land covers to ensure that they were reasonable and made edits as needed. It should also be noted that the Landsat imagery used by the USGS is now over five years old, and some land cover types may have changed since the imagery was taken.

Surface Water Diversions

Annual surface water diversions for agriculture, industrial, and municipal uses are listed in a table for each basin (*Cultural Water Demand*). Data on surface water diversions is also summarized by planning area in the text for these volumes.

Diversion data for the period 1971-1990 were taken from the Department's 1994 *Assessment*. A variety of sources were utilized to determine more recent surface water diversions for the period 1991 through 2003. ADEQ furnished a list of municipal water providers who utilize surface water and the ACC supplied annual reports for some of these providers indicating how much surface water they were diverting and/or delivering. USGS provided data on surface water diversions for agriculture for those basins where the diversions have been metered. Most other surface water diversions had to be determined by the Department through one or more methods including review of existing Department, BOR, county, and consultant reports; analysis of recent aerial photography; Internet and records research; questionnaires and phone interviews; consultation with the USGS; and, limited fieldwork. The Department's Colorado River Management Section was an important data source and provided records of Colorado River water users, locations and annual diversion volumes.

In many cases, the Department had to estimate the quantity of surface water being diverted because the records were nonexistent, imprecise or incomplete. For example, to estimate unmetered surface water diversions for agriculture, the Department made assumptions about the number of cropped acres and water duty. For some irrigated areas, diversion amounts were adjusted to account for basin boundaries. Similarly, for most golf courses determined to be using surface water, the Department estimated diversions based on the number of holes and local irrigation needs for turf. The quantity of surface water diverted by municipal water providers was estimated in some cases based on the number of hookups, an assumed per capita use rate and delivery losses.

As previously mentioned, the quantity of surface water diverted for agricultural, industrial, and municipal use was often unmetered and had to be estimated by the Department. Historic diversions were assumed to represent current conditions and vice versa. if information was not available. Assumptions were also made where water demands were met by combining surface water diversions and well pumpage, but the precise volume of each was not known. Furthermore, it is likely that several relatively small surface water diversions were simply not identified by the Department and not included in the Atlas. The values presented in the Atlas should, therefore, not be considered precise, but they provide an estimate of these diversions and indicate where surface water is an important water source to meet cultural demands. The following conventions were used to round cultural demand values met by surface water diversions:

- 0 to 1,000 acre feet – round to the nearest 50 acre-feet;
- 1,000 to 10,000 acre-feet – round to the nearest 100 acre-feet;
- 10,000 to 100,000 acre-feet – round to the nearest 500 acre-feet; and
- 100,000 to 1,000,000 acre-feet – round to the nearest 1,000 acre-feet.

Finally, it should be noted that surface water diverted into reservoirs and stockponds and through fish hatcheries were not included in the cultural demand tables. Practically all of the surface water diverted by fish hatcheries passes through the facilities and is released for use downstream. Surface water diverted into reservoirs and stockponds may or may not be released for use downstream and some of the stored water may be lost to evaporation.

Well Pumpage

Annual well pumpage for agricultural, industrial, and municipal uses is listed in a table for each basin (*Cultural Water Demand*). Data on well pumpage are also summarized by planning area in the text of the planning area volumes. Well pumpage data for the period 1971 through 1990 are from the

Department's 1994 *Assessment*. For the period 1991 through 2003, the primary data source for well pumpage was the USGS, which describes its methodology, assumptions, and data limitations in the 2005 report *Water Withdrawals for Irrigation, Municipal, Mining, Thermoelectric-Power, and Drainage Uses in Arizona Outside of Active Management Areas, 1991-2000.*

The Department had to adjust the USGS pumpage values for a few basins where mining companies pump from the same wells to supply both industrial and municipal needs and, in other basins where springs have been identified as a water source. The USGS accounted for water use from springs as well pumpage, whereas the Department considers these to be surface water diversions. In addition, the USGS did not evaluate water use by feedlots and golf courses. The Department considers both to be industrial uses and, for the Atlas, estimated well pumpage following methods similar to those used to estimate surface water diversions. To estimate well pumpage for feedlots, the Department identified feedlots by using ADEQ's list of active feedlots in Arizona and, based on the type and number of animal units at each feedlot, applied a consumptive rate.

The quantity of well pumpage for agricultural, industrial and municipal use was not always metered, requiring estimation in some cases. Historic pumpage was assumed to represent current conditions, and vice versa, if information was unavailable. Assumptions were also made where water demands were met by combining well pumpage and surface water diversions, but the precise volume of each was unknown. Lastly, it is likely that several relatively small well withdrawals were simply not identified by the USGS or the Department and are not included in the Atlas. The values presented in the Atlas should, therefore, not be considered precise, but they provide an estimate of pumpage and indicate where well water is an important water source to meet cultural demands. The following conventions were used to round cultural demand values met by well pumpage:

- 0 to 1,000 acre feet – round to the nearest 50 acre-feet;
- 1,000 to 10,000 acre-feet – round to the nearest 100 acre-feet;
- 10,000 to 100,000 acre-feet – round to the nearest 500 acre-feet; and,
- 100,000 to 1,000,000 acre-feet – round to the nearest 1,000 acre-feet.

1.3.6 Drought

Section 1.2.5 of this volume presents drought information for the entire state including a description of Arizona's Drought Preparedness Plan. A statewide map (*Drought Levels Based on Monthly Streamflow Discharge – January 2006)* shows recent drought conditions for selected watersheds. A table (*Drought Levels Based on Percentiles*) presents drought levels identified in the Operational Drought Plan.

Drought is also discussed under the Climate Section of this volume, which contains several graphs and a table. Further discussion of drought conditions in each planning area is presented in Volumes 2 through 8. Drought information was provided by the Department's Drought Planning Section, University of Arizona Cooperative Extension, CLIMAS/Institute for the Study of Planet Earth, and the USGS.

1.3.7 Effluent

Facility Data

Information on facilities that treat and discharge effluent is summarized in a table for each basin (*Effluent Generation*). For each treatment facility, the tables list the name, owner, plant location, population served, volume of effluent treated/generated annually (and the year measured), effluent disposal methods, levels of treatment, and the unserved population.

Primary data sources were the Clean Water Needs (CWN) Surveys sponsored by the Water Infrastructure Financing Authority (WIFA), and annual reports provided by the ACC. CWN Surveys are conducted every four years and are used to assist treatment facilities in obtaining funding. To capture data for as many treatment facilities as possible, survey results from 1996, 2000 and 2004 were used for the Atlas. The ACC regulates private treatment plants and requires that operators file annual reports that sometimes included data on effluent production. The data were supplemented, when possible, with information from facility operators, from ADEQ, (which issues facility discharge permits), and Department reports.

Wastewater treatment is a dynamic industry with frequent changes in plant names, treatment levels and effluent volumes. Although the last CWN survey was conducted in 2004, updated information was not available for all facilities. The Department used the most recent data available, which for some facilities is nearly 10 years old.

Effluent Dependent Waters

The location of effluent-dependent waters, including lakes and stream reaches, are shown on basin-scale maps (*Water Quality Conditions)*. A recent (2005) GIS cover of effluent- dependent waters in Arizona was provided by ADEQ. These reaches are also listed and described by ADEQ in their surface water quality rules (A.A.C. R18-11-113).

1.3.8 Land Ownership

Land ownership information is presented on basin-scale maps (*Land Ownership*) and summarized in the text. Included on the maps are the location of major landowner types (e.g. private, BLM, NPS, etc.) and the percentage that each type comprises of the total basin area. Data on current land ownership was downloaded from the Arizona Land Resource Information System (ALRIS) website maintained by the Arizona State Land Department (SLD).

1.3.9 Lands Survey

A number of Atlas maps show township and range lines. Most lands in Arizona have been mapped according to a rectangular coordinate system known as the Public Lands Survey. Under this survey, lands are divided into “townships” and “sections.” A township is a square parcel of land six miles on each side that is subdivided into 36 equal parts called sections. A section covers one square mile or 640 acres. Because of the earth’s curvature, surveying errors and other factors, not all townships are square, not all townships contain 36 sections, and not all sections contain 640 acres.

Townships are located relative to a point that forms at the intersection of an east-west "baseline" and a north-south "meridian." Locations are referenced as being so many six-mile units, called "Townships", north or south of the baseline and so many six-mile units, called "Ranges," east or west of the meridian. Most of Arizona's townships were surveyed relative to the point of intersection of the Gila and Salt Rivers, referred to as the Gila and Salt River Baseline and Meridian. Approximately 20 townships in Apache County were surveyed from the Navajo Baseline and Meridian established in New Mexico, and a small portion of land near the town of Yuma was surveyed from the San Bernardino Baseline and Meridian established in California.

Townships surveyed from the Gila and Salt River Baseline and Meridian are plotted on all basin-scale maps in the Atlas. This information was digitized from USGS Quads. Townships surveyed from the Navajo and San Bernardino Baselines and Meridians have not been plotted, but these are included on the base map that was used to prepare *Geographic Features* maps. Note that in some areas in Arizona no townships have been surveyed. These include a large portion of the Navajo and Hopi Indian Reservations in northeastern Arizona, a small portion of the San Carlos Indian Reservation in east-central Arizona, and several Spanish land grants in southeastern Arizona. To provide general mapping reference, Department staff protracted these unsurveyed areas extending townships based on the Gila and Salt River Baseline and Meridian into these areas. These unofficial townships are included on maps in the Atlas.

1.3.10 Population

Population data are listed in a table for each basin (*Cultural Water Demands).* The tables include yearly estimates of population from 1980-2003 and population projections every 10 years from 2010-2050. Data from the U.S. Bureau of Census (Census) were used to estimate past populations and Arizona Department of Economic Security (DES) 1997 data were used for population projections. (The data were the latest available at time of publication).

The Census provided spatial data for the years 1980, 1990 and 2000, which were organized into tracts (largest), groups, and blocks (smallest). Using GIS software, the Department divided the Census blocks into their respective basins and, as necessary, proportionally split by area those blocks that covered two or more basins. Populations between Census years were estimated by straight-line interpolation.

DES provided projections of how the population in Census places, such as towns and cities, would change in the future. The Department identified the Census places in each basin and applied the projected DES population change, as a percentage, to the 2000 Census data. If more than one Census place occurred in the same basin, the projected changes were averaged and applied across the basin. For three basins (Dripping Springs Wash, Paria, and San Simon Wash) there was insufficient data to make population projections and it was assumed that basin populations have been and will remain the same from 2001 through 2050.

1.3.11 Reservoirs

Location, Capacity and Use

Information on large and small reservoirs is summarized in a table for each basin (*Large and Small Reservoirs and Stockponds*) and locations of the large reservoirs are shown on basin-scale maps (*Surface Water Conditions*). Natural water bodies, such as dry and intermittent lakes, as well as man-made reservoirs, are included.

Large reservoirs are defined in the Atlas as water bodies with a maximum storage capacity of 500 acre-feet or greater, or where capacity data were unavailable to the Department, a maximum surface area of 50 acres or greater. Small reservoirs are defined as water bodies with a capacity of greater than 15 but less than 500 acre-feet, or a maximum surface area of between 5 and 50 acres. The tables list the name of each large reservoirs and the name of the dam (if different), the owner/operator, the maximum storage or surface area, its use (recreation, power, water supply, etc.) and jurisdiction (federal, state, tribal or private). The tables also list the total number of small reservoirs in a particular basin and their combined maximum storage capacity and surface area.

Reservoir information was obtained from 5 primary data sources:

- National Inventory of Dams maintained by the U.S. Army Corps of Engineers;
- The Department's database of jurisdictional and non-jurisdictional dams in Arizona;
- Arizona Game & Fish Department's waterways file and lake classification study;
- Digital versions of 1:100,000 scale USGS topographic maps; and
- The Department's registry of surface water right filings (see further discussion in this section under 'Stockponds') and adjudication reports.

For consistency, the Atlas lists maximum storage capacities for most large reservoirs. When these values were not available, normal storage capacities are presented and noted or, as described above, maximum surface area is presented. Several reservoirs were identified by more than one data source. To avoid duplication, reservoir locations were compared and the most recent data source was typically used. In most cases, reservoir locations presented in the Atlas represent the center of the reservoir, but in some cases, it marks the middle of the dam.

For the purpose of establishing dam jurisdiction, large reservoirs located on federal lands, such as national forests and national parks, were assumed to be under federal jurisdiction. Similarly, large reservoirs located on tribal lands were assumed to be under tribal jurisdiction. Some reservoirs listed in the data sources probably no longer exist, either because they have filled in with sediment and/or have been breached. Where more recent information indicates that a dam has filled with sediment or has been breached, it was not included in the Atlas.

Storage Trends

Historic trends in the storage of several major reservoirs in Arizona is described in the text and summarized in a table (*Arizona Mean Reservoir Levels from 1971-2005)* in Section 1.2.2 of this volume. This information was compiled by CLIMAS using data from NRCS and from the Department's Colorado River Section.

1.3.12 Rural Watershed Initiative Partnerships

Arizona's Rural Watershed Initiative Partnerships are described and shown on a state-scale map (*Rural Watershed Initiative Partnerships)* in Volume I, Appendix B. The table presents a list of all active partnerships, their activities, accomplishments, and identified issues. The same information is presented in tables by planning area in Volumes 2 through 7.

The Regional Water Planning Office at the Department tracks the status of the partnerships and provided the partnership information presented in the Atlas. Note that the issues identified by partnership participants may not represent all of the water resource issues currently faced in rural Arizona.

1.3.13 Rural Water Issues

Rural water issues are summarized in tables (*2003 Rural Questionnaire Issues Identified by Planning Area* and *2004 Rural Questionnaire Issues Identified by Planning Area*) with explanatory text for the entire state in Section 1.2.5 of this volume and in Volume 9 as well as in separate tables (*Planning Area Issues Identified from the 2003 and 2004 Rural Questionnaires*) for each planning area in Volumes 2 through 7. Issues were primarily identified through two questionnaires sent out by the Department in 2003 and 2004. Results from the 2003 questionnaire are summarized in the Department's *Rural Water Resources 2003 Questionnaire Report*. Other issues were identified through Arizona's Rural Watershed Initiative Program.

Data from the Department's questionnaires were entered into a database and queried for various attributes such as total responses, responses by location, issues ranking, type of respondent, etc. Note that the 2003 and 2004 questionnaires were not identical and some questions were asked differently. Also, the number of respondents did not represent a statistically valid sample. Therefore, any conclusions drawn from the questionnaires should, not be considered representative of all of rural Arizona or even representative of a given planning area or basin. Issues can vary dramatically by respondent and location.

1.3.14 Springs

Major and minor springs are listed in a table for each basin (*Springs*). A spring was considered 'major' if its discharge was 10 gallons per minute (gpm) or greater and 'minor' if its discharge was between 1 and 10 gpm. The tables include the name of the major and minor springs, their location (latitude/longitude), the most recent discharge measurement, and the measurement date. The tables also include an estimate of the total number of springs, regardless of discharge, that have been mapped in the basin. Locations of the major springs are shown on basin-scale maps (*Perennial/Intermittent Streams and Major (≥10 gpm) Springs)*.

Spring data were obtained from a variety of sources, most notably the USGS, which maintains a database of spring discharge records. Reports by universities and public land agencies such as the U.S. Forest Service, National Park Service, and BLM were also useful. To estimate the total number of springs in each basin, the Department downloaded GIS covers from ALRIS and the National Hydrography Data Set (NHD) that incorporate spring locations from the USGS Geographic Names Information System (GNIS or Geonames) database and from USGS Digital Line Graphs (DLGs). ALRIS and NHD do not indicate how or when the USGS located these springs. It is not known whether a detailed, ground survey would now identify more springs or, in light of recent drought conditions, less spring sites.

Many of the springs with discharge data were listed in more than one data source. To avoid over-counting, the Department compared spring names, locations, discharge rates, and dates of measurement and removed obvious duplicates. Topographic maps were also checked to verify that the springs had been mapped. Those springs not verified on topographic maps were included in the Atlas but noted accordingly. For most springs, the location and point of discharge measurement were, for practical purposes, the same. But in some areas, particularly the Grand Canyon, access was poor and discharge measurements had to be made at a point significantly downstream of the spring orifice.

The Atlas generally presents the most recent discharge measurement identified at a spring site. However, for springs fed by shallow water sources, discharge rates can vary dramatically from year to year or even from day to day. To address this issue, some springs were included in the Atlas even if their last discharge measurement had dropped below 10 gpm for major springs or 1 gpm for minor springs. For these springs, the date of measurement is an earlier date when the discharge was greater.

1.3.15 Stockponds

An estimate of the total number of stockponds is listed in a table for each basin (*Large and Small Reservoirs and Stockponds*). The estimates are based on analysis of the Department's surface water registry. The registry includes the following water right filings:

- Applications to appropriate public water, permits and certificates of water right (Department file numbers beginning with "33", also known as "33s");
- Water right registrations filed pursuant to the Water Rights Registration Act of 1974 ("36s");
- Stockpond registrations filed pursuant to the Registration of Stockponds Act of 1977 ("38s");
- Statement of claimants filed by Indian tribes, or the federal government on their behalf, as part of the Gila River and Little Colorado River Adjudications ("39s"); and,
- Court decreed water rights ("4As" and "BBs").

Only those filings for ponds with a capacity of 15 acre-feet or less were considered. Because the same stockpond can often have 2 or more associated filings, an effort was also made to avoid overcounting the number of ponds by comparing stockpond names and locations and eliminating duplicates. Stockpond locations were not verified through field investigations or by analysis of topographic maps and aerial photographs. As a result, it is unknown whether additional ponds exist but were never claimed, or whether the ponds that were claimed are still in use. In areas of the state where stockpond locations have been previously verified, estimates based only on water right filings appear to be within an order of magnitude.

1.3.16 Streams

Diversions (see Cultural Water Demands)

Flood Warning (ALERT) Gages

The location of flood warning gages is shown on basin-scale maps (*Surface Water Conditions*) and information related to these gages is summarized in a table for each basin (*Stream Gage Data*). The tables include the name and identification number of the gaging stations, station types (precipitation, stage, repeater, or some combination of these), dates of installation, and who is responsible for operation and maintenance (flood control districts, cities, etc.).

This information was obtained from the Department's Office of Water Engineering, which maintains a database of flood warning equipment across Arizona. The Department's database was queried in Fall 2005 and the information presented in the Atlas was accurate at that time. According to staff at the Office of Water Engineering, new flood warning gages are routinely added to the ALERT (Automated Local Evaluation in Real Time) network so the current number of stations may be greater than presented.

Flow Gages

The location of USGS streamflow gages is shown on basin-scale maps (*Surface Water Conditions*) and information related to the gages is summarized in a table for each basin (*Stream Gage Data*). The tables include the following information for all continuous flow gages, active or discontinued, with at least one year of record:

- Name and identification number of the station;
- Area and mean elevation of the gaged drainage basin;
- Period of record;
- Average seasonal streamflows, as a percentage of annual flow;
- Annual streamflow statistics (minimum, median, mean, and maximum); and,
- Number of years of annual streamflow data used to calculate statistics.

The Atlas does not include data from USGS peak flow gages or from continuous flow gages with less than one year of record.

Gage information was obtained from various USGS sources including their National Water Information System (NWIS) on-line database, recent (Water Years 2002 and 2003) Water-Data Reports, and a 1998 report that summarizes streamflow data and drainage basin characteristics for selected gaging stations. The Department calculated average seasonal streamflows using mean monthly streamflow data downloaded from NWIS. It should be noted that mean streamflow values in the Southwest may be affected by a few, larger flows, which are common in the region. Seasons were defined in the Atlas as follows:

- Winter – January through March;
- Spring – April through June;
- Summer – July through September; and
- Fall – October through December.

Annual streamflow statistics were similarly calculated, but using mean annual streamflow data downloaded from NWIS. Note that annual statistics were not necessarily run on a gage's entire period of record, as the USGS only calculates annual mean streamflows for years with a complete 12-month dataset. Note also that annual statistics are only presented for gages with 3 or more years of record and all calculations are based on the Calendar Year, not Water Year. Average seasonal streamflows were calculated using data collected through September 2005 and annual streamflow statistics were calculated using data collected through December 2004.

Streamflow statistics are affected by the length of record (e.g. 3 years vs. 50 years of data) as well as the hydrologic conditions occurring when the data were collected (e.g. drought vs. wet period). In addition, isolated conditions may affect streamflow at one station but not at another station nearby. In light of these constraints, the statistics presented in the Atlas should only be used as a general indication of streamflow conditions in the basins and not for site-specific studies.

Instream Flow

Information on instream flows is summarized in a table for each planning area (*Instream Flow Applications and Permits)* and shown on planning-area maps *(Location of Instream Flow Applications and Permits*). The tables include the name of stream reaches with instream flow claims, the name of applicants who have filed for instream flow rights, application numbers and dates of filing and, whether applications have been permitted and certificated by the Department. This information was provided by the Water Management Support Section at the Department, which maintains a database that tracks the status of instream flow applications.

Intermittent and Perennial Reaches

Recent perennial and intermittent streams are shown on basin-scale maps (*Perennial/Intermittent Streams and Major (≥10 gpm) Springs)* and on planning-scale maps *(Location of Instream Flow Permits and Applications*).

Locations of perennial streams were taken from a 1993 report prepared by the Arizona Game and Fish Department (AGFD) as part of the Statewide Riparian Inventory and Mapping (SRIM) Project. In that report, AGFD identified perennial reaches based on a 1981 AGFD map that AGFD revised after consultation with several government agencies (the Department, ADEQ, BLM, and USFS), private sector hydrologists, and academicians. Locations of intermittent streams were taken from a 1997 AGFD report prepared during the last phase of the SRIM Project. Intermittent stream reaches were identified on topographic maps by staff of AGFD, BLM, NPS, and USFS.

Due to the prolonged drought currently affecting Arizona, some of the perennial stream reaches identified by AGFD may now be intermittent and some of the intermittent reaches may now be ephemeral. As climatic conditions change in the future, it is expected that many of these streams will likely return to their previously classified flow conditions, except where impacted by development.

Major Drainages

Major stream drainages are shown on basin-scale maps (*Surface Water Conditions*). Drainage locations were taken from ALRIS, which provides a GIS cover of Arizona streams. The ALRIS stream cover is based on 1:100,000 scale USGS topographic maps that were enhanced with data from EPA and several state agencies.

ALRIS classifies streams into five cartographic orders based generally on drainage basin size. Cartographic Order 1 streams drain the largest areas and include major rivers like the Colorado, Verde, Salt, Gila, etc. The *Surface Water Conditions* maps show the location of Cartographic Order 1, 2 and 3 streams and includes stream names for the first two orders.

Runoff

Average annual or 'unit' runoff contours are plotted on basin-scale maps (*Surface Water Conditions*). The contours show the magnitude and spatial variation in runoff, in inches per year, based on streamflow data collected by the USGS during 1951 through 1980. The data reflects the runoff in tributary streams, rather than in major rivers, as an indication of how runoff varies regionally with precipitation and other geographic features.

The streamflow data were compiled by the USGS in 1985 and, in 1987, a 1:2,000,000-scale unit-runoff contour map of the conterminous United States was published. The map has since been digitized and posted on the USGS website, the Department downloaded it for use in the Atlas.

1.3.17 Water Protection Fund

Information on Water Protection Fund grants is summarized in a table (*Arizona Water Protection Fund Grant Summary)* and shown on a state-scale map *(Arizona Water Protection Fund Grant Locations)* in Appendix C of this Volume. The table includes grant numbers issued through FY 2005, project titles and categories, and associated groundwater basins. Similar information is also presented in tables by planning area in Volumes 2 through 8.

The tables and map are based on a database maintained by the Department's Drought, Conservation, and Riparian Planning Section. For purposes of the Atlas, Water Protection Fund projects were grouped into categories by type (watershed restoration, revegetation, research, etc.) and organized by groundwater basin.

1.3.18 Water Quality

Water quality data are summarized in tables for each basin (*Water Quality Exceedences*) and sample locations are shown on basin-scale maps (*Water Quality Conditions*). The maps show the location of wells, springs, and mines that have exceeded drinking water standards and lakes and streams that are impaired for designated uses. Tables for the wells, springs, and mines list the type of sampling site, its location (township, range and section), and which water quality parameters have exceeded standards for drinking water. Tables for the lakes and streams list the name and type of impaired water body, its length (streams) or area (lakes), and which water quality parameters have exceeded designated uses standards. Sample dates and parameter concentrations are not included in the tables, but this information has been compiled by the Department and is available for review.

Water quality data for the wells, springs, and mines were obtained from the following primary sources:

- The Department's Groundwater Site Inventory (GWSI) database;
- USGS's National Water Inventory System (NWIS) database;
- ADEQ's Safe Drinking Water (SDW), Rural Watershed Study, and Arsenic databases; and
- Various technical reports prepared by the Department, ADEQ and USGS.

Data on impaired lakes and streams comes from ADEQ's 2005 report *The Status of Water Quality in Arizona – 2004, Arizona's Integrated 305(b) Assessment and 303(d) Listing Report*.

Several of the well, spring, and mine sites have been sampled more than once and/or results from the same sampling date are listed in more than one data source. An effort was made to remove duplicate data using available information on site location. The water quality data presented in the Atlas indicate areas where water quality exceedences have previously occurred. Additional areas of concern may currently exist where water quality samples have not been collected or sample results were not reviewed by the Department. For example, as part of ADEQ's Underground Storage Tank (UST) and Aquifer Protection Permit (APP) programs, literally thousands of water quality samples have been collected and analyzed. Results from these analyses were not included in the Atlas. What is included for these and other environmental programs is a current (2006) map from ADEQ that shows the location of contaminated sites across the state (See *Contamination Sites,* section 1.3.4).

Finally, please note that the water quality exceedences presented in the Atlas may or may not reflect current aquifer conditions and probably do not reflect the quality of water being supplied by local water providers in the area. The latter are required by state law to supply water that meets drinking water standards. The Atlas indicates areas where private well owners and surface water users may want to test the quality of their water or restrict its use.

1.3.19 Wells

Automated Recorder Sites

The location and type of automatic water-level recorders are shown on a statewide map (*Automatic Water-level Recorder Sites as of 2005*) in Section 1.2.5 of this volume and in Volume 8 for AMAs. Automatic water-level recorders collect numerous measurements daily, filling in the gaps between annual measurements. The types of recorders include analog or chart, digital, and real-time digital. Information on recorder sites comes from the Department's Basic Data Unit, USGS, and the Cities of Flagstaff and Williams. It is assumed that the recorders are currently operational. Well inspections are needed to verify this assumption for all sites.

Basin Sweeps

The date of the most recent well sweep and the number of wells measured during the sweep is listed in a table for each basin (*Hydrogeology*). Information on well sweeps comes from the Department's Groundwater Site Inventory (GWSI) database. A well sweep refers to a large number of measurements of water levels in wells throughout a basin. While efforts are made to target specific wells, the process is largely random in nature, and is intended to provide the best aerial and vertical coverage in the basin. It is not intended to, and does not include every well in the basin.

Index Sites

The number of index wells is listed in a table for each basin (*Hydrogeology*). Water levels in index wells are measured manually at specific times, or continuously using automatic recording devices. These wells are representative of aquifer conditions over a large geographic area and their measurement allows a lower density of monitoring to occur in years between basin sweeps.

Information on index wells came primarily from the Department's GWSI database. This was supplemented with information from the USGS, other federal entities (Fort Huachuca, NPS, and USBR), an Indian Tribe (Navajo Nation), a city (Flagstaff), and two utilities (SRP and TEPCO).

Number of Completions

Numbers of registered water supply wells are listed in a table for each basin (*Cultural Demands*). The tables include the total number of wells completed through 1980, the number of new wells completed in 5-year increments from 1981 through 2000, and the number of new wells completed between 2001 and 2003. Also included is the total number of wells drilled without completion dates.

Information on well completions comes from the Department's well registry, commonly referred to as the "Wells 55" database. Wells in the registry were queried first by basin and reported pump capacity. This resulted in two well lists for each basin – wells with a maximum pump capacity of 35 gallons per minute (gpm) or less and wells with a maximum pump capacity greater than 35 gpm. In the AMAs, wells with a maximum pump capacity of greater than 35 gpm are "non-exempt" wells and wells with a maximum pump capacity of 35 gpm or less are "exempt" wells. The resulting well lists were then filtered to exclude registrations for wells that apparently were never drilled and/or those wells not used for water supply purposes.

The Department's wells registry only lists data for wells that have been registered with the Department, as required by statute. For the purpose of the Atlas, no attempt was made to verify the accuracy of the data or to conduct field surveys to determine whether additional wells have been drilled but never registered or whether the wells that were drilled and registered are still operable today. For example, wells drilled on Indian Reservations are generally not counted since the tribes have no requirement to register these wells with the Department.

Pumpage (see Cultural Water Demands)

Recent Water-Level Depths

Recent (2003 or 2004) depths to water in wells are shown on basin-scale maps (*Groundwater Level Conditions*). Depth values, in feet below land surface, are presented on the maps next to each well symbol. Most of the water level data were taken from the Department's GWSI database. These data were supplemented with measurements made by the USGS, other federal entities (Fort Huachuca, NPS, and USBR), an Indian Tribe (NTUA), a city (Flagstaff), and two utilities (SRP and TEPCO).

All water levels were reviewed and data that appeared unreasonable were excluded from the Atlas. Some of the included data were adjusted first to ensure consistency and account for the different measurement methods used.

Water-level Changes

Water-level changes in wells are shown on basin-scale maps (*Ground-water Level Conditions*) and on hydrographs for each basin (*Selected Basin Hydrographs*). The maps use colored dots to show how water levels have changed over a 13-year period that began in about fall 1990 and ended in spring 2004. Five different colors are used to represent the range of recorded water-level changes. A positive change indicates a rise in water level over the period and negative change indicates a decline. The hydrographs show water-level changes for selected wells over the 30-year period from January 1975 to January 2005. Included on the hydrographs are a well identifier, total well depth, principal aquifer, and water use. Care was taken to select wells that were representative of aquifer conditions both horizontally and vertically.

Most of the water-level data used to generate the maps and hydrographs were taken from the Department's GWSI database. These data were supplemented with measurements made by the USGS, other federal entities (Fort Huachuca, NPS, and USBR), an Indian Tribe (Navajo Nation), a city (Flagstaff), and two utilities (SRP and TEPCO). All water levels were reviewed and data that appeared unreasonable were excluded from the Atlas. Some of the included data were adjusted to ensure consistency and account for the different measurement methods used.

An effort was made to use data collected during the period when the wells were not actively being pumped or only minimally pumped. This period was typically from about September through about May. However, in some areas, like the Navajo Reservation, water-level data from wells were less abundant and the data used in the Atlas may have been affected by pumping.

Yields

Wells yields are listed in a table for each basin (*Hydrogeology*) and shown on basin-scale maps (*Well Yields*). The maps use colored dots to show the location of well yields measured by the Department and USGS. Five different colors are used on the maps to represent the range of recorded well discharges. The tables list summary statistics for these and other estimates of well yield.

Information on well yields was primarily taken from databases maintained by the Department (GWSI and Wells55) and USGS (NWIS). Also used was a 1990 internal report by the Department that summarizes water resources information by basin and a 1994 annual report by USGS on groundwater conditions across Arizona. To estimate well yields using the Wells55 database, only wells with a casing diameter greater than 10 inches were considered. It was assumed that such wells were drilled to produce a maximum amount of water and, therefore, their reported pump capacities are indicative of the aquifer's potential to yield water to a well.

Many factors can affect well yields, including local and regional aquifer properties, well design, the size and condition of the pump, and the age of the well. The data presented in the Atlas provides a general indication of the quantity of water that can be produced from basin aquifers under optimal well conditions. Actual well yields may be significantly lower than those presented based on the factors described.

SECTION 1.4 Observations

This section contains brief observations regarding the data and information compiled in the Atlas and its utility and constraints. Also summarized are water resource planning considerations including regional cooperation and statewide influences.

Data Compilation and Analysis

The process of compiling data for the Atlas revealed that water resource data are often dispersed and not always readily available. The methods section above does not fully reflect the level of effort required to assemble the data presented in the Atlas. Differences in database design and other factors can make data sharing between water-resource agencies and institutions difficult.

It is also apparent that a number of databases contain inconsistent or occasionally incorrect data and there is a critical need for quality control. Agencies have different data classification systems and regulatory or management definitions. These conditions need to be recognized when collecting and evaluating data. Database maintenance can be a challenge for cash-strapped agencies that often lack the necessary resources to devote to data management and data retrieval therefore can be a challenge. In cases where data is collected through a public reporting process, the quality of the data is dependent on the accuracy of public measurement and reporting.

Data Access

The Atlas structure is intended to provide water-related information on a variety of scales; from a relatively local level (groundwater basins) to a more regional perspective (multiple-basins and planning areas). This should help support some non-AMA planning efforts. An objective of the Atlas is to improve access to this information by regular updates and construction of a data retrieval system and eventually an interactive product. Regular data exchange between water resource agencies and institutions would help this effort.

Water Resource Planning, Assistance and Coordination

Water resource data is critical to evaluate conditions and develop water resource plans. However, planning and financial assistance may also be needed by communities and regional partnerships. Lack of financial resources for infrastructure improvements was cited by a majority of respondents to the rural surveys conducted in 2003 and 2004. It is clear that additional mechanisms need to be developed to address this need.

Planning assistance has been provided by the Department under the Rural Watershed Initiative Program since the late 1990’s but the program has not been consistently funded at a level sufficient to conduct all necessary studies. Some planning assistance is also offered by the Department for development of Water System Plans required by HB 2277, primarily through a guidance document and workshops. Additional water resource planning assistance would be helpful to many smaller communities.

A number of non-AMA Partnerships work collaboratively to address local water resource issues. Through inter-jurisdictional agreements, some have entered into long-term commitments to identify solutions, fund projects and meet management goals. The 2005 legislation requiring water system plans (HB2277) supports collaborative efforts by authorizing development of joint water supply plans by two or more water providers serving the same area. In some areas, stakeholders desire regulatory tools to manage water supplies and are evaluating options to expand their authorities. This may require a coordinated statewide effort to develop the necessary management mechanisms. It is clear that working collaboratively provides multiple benefits including opportunities for information sharing, resource development, consistency in conservation messaging, and cost-sharing.

Statewide Perspective

Although the Atlas is organized by groundwater basins, planning areas and AMAs, it is evident that as Arizona grows, water resource utilization is increasingly influenced by statewide and regional conditions. For example, lack of snowpack in Colorado impacts the availability of Colorado River water supplies to some users in Arizona. This may result in the need to use local groundwater supplies in communities that have not found it necessary in the past to invest in groundwater infrastructure development. Elsewhere, communities that may have relied on an in-state surface water supply may need to forego use of the supply to satisfy water rights claims of senior downstream users. Scenarios like this illustrate that water management and planning often needs to extend beyond local boundaries and that there is an interrelationship between many areas of the state, whether they be within an AMA or outside an AMA. Many of the state's water resource managers and rural partnerships already recognize this reality. It is hoped that the information contained in the Atlas provides some of the tools to begin or enhance water planning efforts at both a local and more regional level.

REFERENCES

ADEQUACY DETERMINATIONS

ADWR, 2005, Databases of Assured and Adequate water supply determination: ADWR Office of Assured and Adequate Water Supply.

ADWR, 2006, Project files for assured and adequate water supply applications: ADWR Hydrology Division.

AQUIFERS

Flow Direction

IN VOLUMES 2-8

Major Types

ADWR, 1994b, Arizona Water Resources Assessment, Vol. II, Hydrologic Summary.

Recharge and Storage

ADWR, 1994b, Arizona Water Resources Assessment, Vol. II, Hydrologic Summary.

Anderson, T.A., and Freethey, G.W., 1995, Simulation of ground-water flow in alluvial basins in south-central Arizona and parts of adjacent states: US Geological Survey (USGS) Professional Paper 1406-D, 77 p.

Arizona Water Commission, 1975, Summary, Phase I, Arizona State Water Plan, Inventory of resource and uses.

Freethey, G.W. and Anderson, T.W. 1986, Predevelopment hydrologic conditions in the alluvial basins of Arizona and adjacent parts of California and New Mexico: USGS Hydrologic Investigations Atlas-HA664.

Sundie, D.W., 1990, Draft outline of basin profiles for the state water assessment: ADWR Statewide Planning Division, Memorandum to L. Linser, January 16, 1990.

CLIMATE

Average Annual Precipitation

Oregon State University, 2006, PRISM map showing average annual precipitation in Arizona for 1961-1990: Spatial Climate Analysis Service (SCAS), accessed in 2005 at www.ocs.orst.edu/prism.

Evaporation Stations

Arizona Meteorological Network (AZMET), 2005, Evaporation data from climatological stations: Accessed December 2005 at http://www.ag.arizona.edu/azmet/locate.html

Western Regional Climate Center (WRCC), 2005, Pan Evaporation Station data: Accessed December 2005 at http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~GetCity~USA

Precipitation and Temperature Stations

WRCC, 2005, Precipitation and temperature station data: Accessed December 2005 at http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~GetCity~USA.

Snowfall Stations

Natural Resources Conservation Service (NRCS), 2005, SNOTEL (Snowpack Telemetry) station data: Accessed December 2005 at http://www3.wcc.nrcs.usda.gov/nwcc/sntlsites.jsp?state=AZ. NRCS, 2005, Snow Course station data: Accessed December 2005 at http://www.wcc.nrcs.usda.gov/nwcc/snow-course-sites.jsp?state=AZ.

Statewide Evaporation Conditions

Arizona Water Commission, 1975, Summary, Phase 1-Arizona State Water Plan, Inventory of resource and uses.

Farnsworth, R.K., Thompson, E.S. and Peck, E.L., 1982, Evaporation atlas for the contiguous 48 United States: NOAA Technical Report NWS 33.

Meyers, J.S., and Nordenson, T.J.,1962, Evaporation from the 17 western states: USGS Professional Paper 272-D.

US Bureau of Reclamation (USBOR), 2004, Colorado River System consumptive uses and losses report 1996-2000.

Trends in Precipitation and Temperature

Climate Assessment for the Southwest (CLIMAS), 2005, Drought data: Accessed December 2005 at http://www.ispe.arizona.edu/climas.

ADWR, 1994c, Arizona Riparian Protection Program Legislative Report

ADWR, 2005, Upper San Pedro Basin Active Management Area Review Report.

Governor's Drought Task Force, 2004a, Arizona Drought Preparedness Plan, Background and Impact Assessment Section.

Salzer, M.W. and Kipfmueller, K.F., 2005, Reconstructed temperature and precipitation on a millennial timescale from tree-rings in the Southern Colorado Plateau, U.S.A: Climatic Change 70, pp. 465-87.

Sheppard, P.R., Comrie, A.C., Packin, G.D., Angersbach, K. and Hughes, M.K. 2002, The climate of the Southwest: Climate Research 21, pp. 219-238.

CONTAMINATION SITES

ADEQ, 2006, GIS cover of active DOD, Superfund, WQARF, and LUST contamination sites in Arizona: ADEQ data file received February 2006.

DEQ, 2006, Brownsfields Tracking System: Accessed June 2006 at http://www.azdeq.gov/databases/brownsearch.html.

CULTURAL WATER DEMAND

Location of Major Water Users

Arizona Agricultural Statistic Service (AASS), 2005, Historic swine demand in Navajo County for years 1991, 1996, 2000, 2002: Accessed September 2005 at http://www.nass.usda.gov/Statistics by State/Arizona/index.asp.

Arizona Crop and Livestock Reporting Service, 1973, 1972 Arizona Agricultural Statistics: Bulletin S-8.

ADWR, 2005, Water use by golf courses in rural Arizona: Unpublished analysis by ADWR Office of Regional Strategic Planning.

Arizona Department of Mines and Mineral Resources (ADMMR), 2005, Database of active mines in Arizona: Accessed at http:// www.admmr.state.az.us.

Hollis, 2005, Swine Water Requirements: Accessed October 2005 at http://www.ag.uiuc.edu/archives/experts/swine/1997archive/0031.html.

USGS, 2004, Southwest Regional Gap analysis study-land cover descriptions: Accessed January 2005 at http://earth.gis.usu.edu/swgap.

Surface Water Diversions

ACC, 2005, Annual reports for years 1990 to 2005 for small water providers: ACC Utilities Division, July 2005.

ADEQ, 2005, ADEQWATP database: ADEQ data file received May 16, 2005.

ADEQ, 2005, ADEQSWI database: ADEQ data file received September 14, 2005.

ADEQ, 2005, Database of surface water sources used by water providers: ADEQ data file received June 25, 2005.

ADWR, 1994a, Arizona Water Resources Assessment, Vol. I-Inventory and Analysis.

ADWR, 2004, Data from 2003 rural water resources questionnaire: ADWR Office of Resource Assessment Planning.

ADWR, 2005, Data from 2004 rural water provider questionnaire: ADWR Office of Resource Assessment Planning.

ADWR, 2005, Agricultural Surface Water Use Estimates: Unpublished analysis by ADWR Office of Resource Assessment Planning.

ADWR, 2006, Database of CAP diversions: ADWR Office of Colorado River Management.

Tadayon, S., 2004, Water withdrawals for irrigation, municipal, mining, thermoelectric-power, and drainage uses in Arizona outside of the active management areas, 1991-2000: USGS Scientific Investigations Report 2004-5293, 27 pp.

Well Pumpage

ADEQ, 2005, Database of active dairy farms & feedlots: ADEQ data file received October 2005.

ADWR, 1994a, Arizona Water Resources Assessment, Vol. I- Inventory and Analysis.

ADWR, 1999, Pinal AMA Third Management Plan, Chapter 6, 2000-2010.

Tadayon, S., 2004, Water withdrawals for irrigation, municipal, mining, thermoelectric-power, and drainage uses in Arizona outside of the active management areas, 1991-2000: USGS Scientific Investigations Report 2004-5293, 27 pp.

DROUGHT

CLIMAS, 2005, Drought data: Accessed December 2005 and March 2006 at http://www.ispe.arizona.edu/climas.

Governor's Drought Task Force, 2004b, Arizona Drought Preparedness Plan, Operational Drought Plan Hirschboeck, K.K., and Meko, D.M., 2005, A tree-ring assessment of synchronous extreme streamflow episodes in the Upper Colorado & Salt-Verde-Tonto River basins: University of Arizona, Laboratory of Tree-Ring Research, final report to the Salt River Project.

Stahle, D.W., Cook, E.R., Cleaveland, M.K., Therrell, M.D., Meko, D.M., Grissino-Mayer, H.D., Watson, E., and B.H. Luckman, B.H., 2000, Tree-ring data document 16th century megadrought over North America: Eos, Transactions of the American Geophysical Union 8(12): 212, 125.

EFFLUENT

Facility Data

ACC, 2005, Annual reports for years 1990 to 2005 for private sewer companies: ACC Utilities Division, June 2005.

ADEQ, 2005, ADEQWWTP Database: ADEQ data file received August 2005.

ADEQ, 2005, Azurite Database: ADEQ data file received September 2005.

ADEQ, 2005, WWTP and permit files: Miscellaneous working files reviewed July 2005.

EPA, 2003, Wastewater systems improvements project environmental assessment, City of Bisbee, Cochise County Arizona.

EPA, 2005, 2000 and 1996, Clean Watershed Needs Survey databases: Accessed March 2005 at http://www.epa.gov/owm/mtb/cwns/index.htm.

ADWR, 1991, Hydrologic Survey Report for the San Pedro River Watershed, Vol. I: General Assessment.

Water Infrastructure Finance Authority of Arizona (WIFA), 2005, Clean Watershed Needs Survey-2004: Unpublished data sheets received July 2005.

WIFA, 2005, Water and Wastewater Residential Rate Survey for the State of Arizona.

Effluent Dependent Waters

ADEQ, 2005, GIS cover of effluent dependent waters: ADEQ data file received December 2005.

Drioll, M., and Marsh, D., 2006, Status of water quality in Arizona-2004 integrated 305(b) assessment and 303(d) listing report: ADEQ.

FEDERAL AGENCIES AND LAWS

ADWR, 1999, Third Management Plan for the Tucson Active Management Area, 2000-2010.

Pearce, Michael J., 2002, Chapter 3.2 Water Law, *In* Arizona Environmental Law Manual, State Bar of Arizona.

Pollack, Stanley M. Esq., 2003, Indian Reserved Rights: Navajo Claims to the Colorado River, *In* Arizona Water Law: CLE International, August 7-8, 2003.

US Fish and Wildlife Service (USFWS), 2005, ESA Basics, 30 Years of Protecting Endangered Species: Accessed October 2005 at http://www.fws.gov/endangered/pbus/ESA_Basics.

LAND OWNERSHIP

Arizona Land Resource Information System **(**ALRIS), 2004, GIS cover of land ownership: Accessed in 2004 at http://www.land.state.az.us/alris/index.html.

GEOGRAPHIC

USGS, 1981, Geographic digital data for 1:500,000 scale maps: USGS National Mapping Program Data Users Guide.

POPULATION

Arizona Department of Economic Security, 2005, Workforce Informer: Accessed August 2005 at http://www.workforce.az.gov.

US Census Bureau, 2006, on-line data files: Accessed January 2006 at www.census.gov.

RESERVOIRS

Location, Capacity, and Use

ADWR, 1994d, Little Colorado River Settlement Committee Group "A" – In basin negotiating committee, inventory of irrigation and reservoirs in the Lower Little Colorado River Watershed.

ADWR, 2005, Database of inspected dams: ADWR Office of Dam Safety.

ADWR, 2005, Database of non-jurisdictional dams: ADWR Office of Dam Safety.

ADWR, 2005, Registry of surface water rights: ADWR Office of Water Management.

ADWR, 2006, Statement of Claimants filed by Indian tribes or the United States on their behalf in the Gila and Little Colorado River Adjudications: ADWR Office of Planning and Adjudications Support.

ALRIS, 2005, GIS cover of water features: Accessed July 2005 at http://www.land.state.az.us/alris/index.html.

Arizona Game and Fish Department (AZG&F), 1982, Arizona Lakes Classification Study: AZG & F Planning Department.

AZG&F, 2005, Arizona Waterways: Data file received April 28, 2005.

US Army Corps of Engineers, 2004 and 2005, National Inventory of Dams-Arizona Dams: Accessed November 2004 to April 2005 at http://crunch.tec.army.mil/nid/webpages/nid.cfm.

Storage Trends

USBOR, 2002, Final Environmental Impact Statement; Implementation Agreement, inadvertent overrun and payback policy and related federal actions.

USBOR, 2006, Reservoir data: Accessed March 2006 and May 2006 at www.usbr.gov/lc and www.usbr.gov.uc.

US Department of Agriculture (USDA) NRCS, 2005, Reservoir reports for Arizona: Accessed December 2005 at www.wcc.nrcs.usda.gov/cgbin/resv_rpt.pl?state=arizona.

RURAL WATER ISSUES

ADWR, 2004, Rural water resources study-Rural Water Resources 2003 Questionnaire Report, October 2004.

ADWR, 2005, Data from 2004 rural water provider questionnaire: ADWR Office of Resource Assessment Planning.

Whitmer, T. 2006, Summary of rural watershed partnership issues: ADWR Office of Regional Strategic Planning.

SPRINGS

ALRIS, 2005, GIS cover of Springs: Accessed January 2006 at **http://www.land.state.az.us/alris/index.html**.

USGS, 2006, Database of springs and spring discharges: Received November 2004 and January 2006 from USGS office in Tucson, AZ.

STOCKPONDS

ADWR, 2005, Registry of surface water rights: ADWR, Office of Water Management.

STREAMS

Diversions (see Cultural Water Demands)

Flood Warning Gages

ADWR, 2005, Database of flood warning gages: ADWR Office of Water Engineering.

Flow Gages

Pope, G.L., Rigas, P.D., and Smith, C.F., 1998, Statistical summaries of streamflow data and characteristics of drainage basins for selected streamflow-gaging stations in Arizona through water year 1996: USGS Water Resources Investigations Report 98-4225.

USGS, 2005, National Water Information System (NWIS) data for Arizona: Accessed December 2005 at http://waterdata.usgs.gov/nwis.

USGS, 2002, Water resources data, Arizona, water year 2002: USGS Water Data Report AZ-02-1.

USGS, 2003, Water resources data, Arizona, water year 2003: USGS Water Data Report AZ-03-1.

Instream Flow
ADWR, 2005, Database of instream flow applications: ADWR Office of Water Management.

Intermittent and Perennial Streams
Valencia, R.A., Wennerlund, J.A., Winstead, R.A., Woods, S., Riley, L., Swanson, E., and Olson, S., 1993, Arizona riparian inventory and mapping project: Arizona Game and Fish Department.
Wahl, C.R., Boe, S.R., Wennerlund, R.A., Winstead, R.A., Allison, L.J., Kubly, D.M., 1997, Remote sensing mapping of Arizona intermittent stream riparian areas: Arizona Game and Fish Technical Report 112.

Major Drainages
ALRIS, 2005 GIS cover of Streams: Accessed 2005 at http://www.land.state.az.us/alris/index.html.

Runoff
USGS, 2006, Average annual runoff in the United States, 1951-1980: Data accessed March 2006 at http://aa179.cr.usgs.gov/metadata/wrdmeta/runoff.htm.

WATER PROTECTION FUND
ADWR, 2005, Water Protection Fund database: ADWR Office of Drought, Conservation and Riparian Planning.

WATER QUALITY
ADEQ, 2004, Water quality exceedences for drinking water providers in Arizona: ADEQ data file received September 27, 2004.
ADEQ, 2004, Water quality exceedences by watershed: ADEQ data file, received June 24, 2004.
ADEQ, 2004, Water providers with arsenic concentrations in wells over 10ppb: ADEQ data file, received August 2004.
ADWR, 2005, Groundwater Site Inventory (GWSI): ADWR Hydrology Division.
Diroll, M., and Marsh, D., 2006, Status of water quality in Arizona-2004-integrated 305(b) assessment and 303(d) listing report: ADEQ.
USGS, 2005, NWIS data for Arizona: Accessed March, 2005 at http://waterdata.usgs.gov/nwis.

WATER RESOURCES OVERVIEW
Gelt, J., 1997, Sharing Colorado River water-History, public policy and the Colorado River Compact,: Arroyo, Vol. 10, No. 1, August 1997.
Governor's Drought Task Force, 2004a, Arizona Drought Preparedness Plan, Background and Impact Assessment Section.
Hirschboeck, K.K., and Meko, D.M., 2005, A tree-ring assessment of synchronous extreme streamflow episodes in the Upper Colorado & Salt-Verde-Tonto River basins: University of Arizona, Laboratory of Tree-Ring Research, final report to the Salt River Project, available at URL: http://fp.arizona.edu/khirschboeck/srp.htm.

WELLS
Automated Recorder Sites
ADWR, 2005, Data files for automated recorder sites: ADWR Basic Data Unit.

Basin Sweeps
ADWR, 2005, Groundwater Site Inventory (GWSI) database: ADWR Hydrology Division.

Index Sites
ADWR, 2005, GWSI database: ADWR, Hydrology Division.
Number of Completions
ADWR, 2005, Wells55 database.

Pumpage (see Cultural Water Demands)

Recent Water-Level Depths
ADWR, 2005, GWSI database: ADWR Hydrology Division.

Water-Level Changes
ADWR, 2005, GWSI database: ADWR Hydrology Division.

Yields
ADWR, 2005, GWSI database: ADWR Hydrology Division.
ADWR, 2005, Wells55 database.
Konieczki, A.D. and Wilson, R.P., 1992, Annual summary of ground-water conditions in Arizona, spring 1986 to spring 1987: USGS Open File Report 92-54.
Sundie, D.W., 1990, Draft outline of basin profiles for the state water assessment: ADWR Statewide Planning Division, Memorandum to L. Linser, January, 16, 1990.
USGS, 2005, NWIS data for Arizona: accessed March 2005 at http://waterdata.usgs.gov/nwis.

ACRONYMS AND ABBREVIATIONS

A.A.C.	Arizona Administrative Code
A.R.S.	Arizona Revised Statutes
AACD	Arizona Association of Conservation Districts
ACC	Arizona Corporation Commission
ADEQ	Arizona Department of Environmental Quality
ADWR	Arizona Department of Water Resources
AF	Acre-feet
AGFD	Arizona Game and Fish
ALERT	Automated Local Evaluation in Real Time
ALRIS	Arizona Land Resource Information System
AMA	Active Management Area
APP	Aquifer Protection Permit
ARS	Agricultural Research Service
AWPF	Arizona Water Protection Fund
AWS	Assured Water Supply
AZMET	Arizona Meteorological Network
AWBA	Arizona Water Banking Authority
BIA	Bureau of Indian Affairs (U.S.)
BLM	Bureau of Land Management (U.S.)
BOR	Bureau of Reclamation (U.S.)
CAGRD	Central Arizona Groundwater Replenishment District
CAP	Central Arizona Project
CAWCD	Central Arizona Water Conservation District
CCN	Certificate of Convenience and Necessity
CDP	Census Designated Place
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act - 42 U.S.C. Section 9601 *et seq.*
cfs	Cubic feet per second
CLIMAS	Climate Assessment for the Southwest
CODE	Arizona Groundwater Management Act - A.R.S. § 45-401 *et seq.*
COE	Corps of Engineers (U.S.)
CRWUA	Colorado River Water Users Association
CU	Consumptive use
CWA	Clean Water Act - 33 U.S.C. Section 1251 *et seq.*
Department	Arizona Department of Water Resources
DES	Arizona Department of Economic Security
DLG	Digital Line Graph
DOD	Department of Defense (U.S.)
DOE	Department of Energy (U.S.)
DOI	Department of Interior (U.S.)
DWID	Domestic Water Improvement District
EA	Environmental Assessment
EIS	Environmental Impact Statement
ENSO	El Nino/Southern Oscillation
EPA	Environmental Protection Agency (U.S.)
ESA	Endangered Species Act - 7 U.S.C. 136; 16 U.S.C. 460 *et seq.*

FMIC	Fort McDowell Indian Community
ft bls	Feet below land surface
GPCD	Gallons Per Capita Per Day
GPHUD	Gallons Per Housing Unit Per Day
gpm	Gallons per minute
GPS	Global Positioning Station
GRIC	Gila River Indian Community
GWSI	Groundwater Site Inventory
HCN	Historic Climate Network (U.S.)
HMS	Hydrologic Map Series
HOA	Home Owners Association
HSR	Hydrographic Survey Report
IBWC	International Boundary Water Commission
ID	Irrigation District
INA	Irrigation Non-expansion Area
ISPE	Institute for the Study of Planet Earth (University of Arizona)
LAIAG	Local Area Impact Assessment Group
LCR	Little Colorado River
LUST	Leaking Underground Storage Tank
maf	Million acre-feet
MCL	Maximum Containment Level
mg/l	Milligrams per liter
mgd	Million gallons per day
MSCP	Multi-Species Conservation Plan
NEPA	National Environmental Policy Act - 42 U.S.C. § 4321-4347
NAU	Northern Arizona University
NDEQ	Navajo Department of Environmental Quality
NDWR	Navajo Department of Water Resources
NHA	Navajo Housing Authority
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent to Drill a Well
NPDES	National Pollution Discharge Elimination System
NPL	National Priorities List
NPS	National Park Service (U.S.)
NRA	National Recreation Area
NRCD	Natural Resources Conservation District
NRCS	Natural Resources Conservation Service
NTUA	Navajo Tribal Utility Authority
NWIS	National Water Information System
NWS	National Weather Service
Pan ET	Pan evaporation
PCE	Tetrachloroethylene
P.L.	Public Law
ppb	Parts per billion
ppm	Parts per million
PRISM	Parameter elevation Regression on Independent Slopes Model
PWC	Private Water Company
RCD	Resource Conservation District

RCRA	Resource Conservation and Recovery Act – 42 U.S.C. § 6901 *et seq.*
RRA	Reclamation Reform Act - 43 U.S.C. § 390aa *et seq.*
RVID	Round Valley Irrigation District
SAWRSA	*Southern* Arizona Water *Rights* Settlement Act- P.L. 108-451 (2004)
SCAS	Spatial Climate Analysis Service
SDW	Safe Drinking Water Act- 43 U.S.C. § 300f *et seq.*
Secretary	U.S. Secretary of the Interior
SLD	Arizona State Land Department
SNOTEL	SNOwpack TELemetry
SPRNCA	San Pedro Riparian National Conservation Area
SRP	Salt River Project
TDS	Total dissolved solids
TEPCO	Tucson Electric Power Company
TCE	Trichloroethylene
TMDL	Total maximum daily load
TNC	The Nature Conservancy
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UST	Underground Storage Tank
VOC	Volatile organic compound
WAPA	Western Area Power Administration
WID	Water improvement district
WIFA	Water Infrastructure Funding Authority
WQARF	Water Quality Assurance Revolving Fund
WRCC	Western Regional Climate Center
WWTP	Wastewater treatment plant

DEFINITIONS

Acre-feet (AF): The amount of water it takes to cover one acre of land to the depth of one foot, approximately 325,851 gallons.

Active Management Area (AMA): A geographic area that has been designated pursuant to A.R.S.§ 45-411 as requiring active management of groundwater or, in the case of the Santa Cruz AMA, active management of any water, other than stored water, withdrawn from a well. Subsequent active management areas may be designated through local initiative or by the Director of ADWR.

Advanced primary treatment: The enhanced removal of suspended solids and organic matter in the wastewater treatment process through the use of chemicals and/or filtration.

Advanced treatment I: A wastewater treatment level that is more stringent than secondary treatment and reduces the organic and inorganic substances from the treated wastewater through the use of chemical and physical techniques. It is often referred to as tertiary treatment.

Advanced treatment II: Highest level of wastewater treatment with a BOD < 10 mg/l and/or the removal of nutrients.

Agricultural water use: Water applied to two or more acres of land to produce plants or parts of plants for sale for human consumption or for use as feed for livestock, range livestock or poultry.

Aquifer: A geologic formation that contains sufficient saturated materials to be capable of storing water and transmitting water in useable quantities to a well.

Aquifer recharge: Water added to the aquifer through seepage and infiltration.

Aquifer storage: Water stored underground for future use. Also, water stored pursuant to a permit issued under A.R.S. § 45-831.01, the Underground Water Storage, Savings and Replenishment Program.

Artificial recharge: Water recharged to the aquifer through recharge projects, which may be recovered in the future based on accrued recharge credits.

Baseflow: The part of a stream discharge that is not attributable to direct runoff from precipitation or melting snow. It is sustained by groundwater discharge and may be considered as normal day-to-day flow during most of the year.

Baseline: A surveyed line that serves as a reference to which surveys are coordinated and correlated.

Basin fill: Unconsolidated material such as sand, gravel and silt, eroded from surrounding mountains and deposited in a valley.

Basin sweep: A technique used to collect information on groundwater level conditions by measuring selected wells throughout a basin. Specific and randomly selected wells are measured to provide the best aerial and vertical coverage in the basin.

Calendar year: The 12-month period from January 1 to December 31.

Census blocks: A geographic area bounded by visible and/or invisible features shown on a map prepared by the U.S. Census Bureau. A block is the smallest geographic entity for which the Census Bureau tabulates decennial census data.

Census designated place: A geographic entity that serves as the statistical counterpart of an incorporated place for the purpose of presenting census data for an area with a concentration of population, housing, and commercial structures that is identifiable by name, but is not within an incorporated place.

Consumptive use: The part of the water demand that becomes unavailable for future use because it is evaporated or consumed by the use. Consumptive use also refers to diversions from the mainstream of the Colorado River minus the returns.

Contamination site: A geographic area where the quality of the water and/or soil quality is naturally hazardous to animals or humans or has been impaired by sewage, industrial wastes, or other materials and where remediation is either ongoing, scheduled for the future or not practicable.

Continuous flow gage: Mechanical device placed in a stream that measures the volume of water flowing at that specific location over an extended period of time.

Community Water System: A public water system, as defined in A.R.S. § 49-352(B), that serves at least fifteen service connections used by year-round residents of the area served by the system or that regularly serves at least twenty-five year-round residents of the area served by the system. A person is a year-round resident of the area served by a system if the person's primary residence is served water by that system.

Cultural Water Demand: The quantity of water diverted from streams and reservoirs and pumped from wells for municipal, industrial and agricultural purposes. It should not be confused with “consumptive use”, which refers to the amount of cultural water demand that is lost from the hydrologic system.

Deficit irrigation: The practice of reducing the number of irrigation applications to lower crop production costs while achieving acceptable yields.

Drinking water standards: Criteria developed by the Arizona Department of Environmental Quality and other state and local agencies, the US Public Health Service, and the US Environmental Protection Agency to assure safe water for human consumption.

Drought: A sustained natural reduction in precipitation that results in negative impacts to the environment and human activity.

Dry lake: A basin that formally contained a lake.

Effluent: Water that has been collected in a sanitary sewer for subsequent treatment in a facility that is regulated as a sewage system, disposal plant or wastewater treatment facility. Such water remains effluent until it acquires the characteristics of groundwater or surface water.

Effluent dependent water: Surface waters that would generally be ephemeral, except for the discharge of treated effluent.

Ephemeral stream: A stream or part of a stream that flows only in direct response to precipitation; it receives little or no water from springs, melting snow or other sources; its channel is at all times above the water table.

Evaporation pan: An open tank used to measure the amount of evaporation. The US Department of Commerce Weather Station Class A pan is 4 feet in diameter and 10 inches deep set so the top rim is 16 inches above ground.

Evapotranspiration: Loss of water from the land through transpiration of plants and evaporation from the soil and surface water bodies.

Exempt well: Within an AMA, a well having a pump with a maximum pumping capacity of 35 gallons per minute or less, which is used to withdraw groundwater for non-irrigation purposes. This term is also used to describe any well outside an AMA having a pump with a maximum pumping capacity of 35 gallons per minute or less.

Groundwater: Generally, water below the earth's surface but commonly applied to water in fully saturated soils and geologic formations.

Groundwater flow model: A digital computer model that calculates a hydraulic head field for the modeling domain using numerical methods to arrive at an approximate solution to the differential equation of groundwater flow.

Hydrographs: A graphic representation of the changes in the flow of water or the elevation of water levels over time.

Igneous rock: A rock formed by the crystallization of magma or lava.

Impaired: A lake or stream that is not meeting one or more surface water quality standards as established in A.R.S. § 49-231

Incidental recharge: The percolation of water to the water table after the water has been used. Components of incidental recharge include recharge that occurs from septic tanks, turf watering and effluent discharge.

Index well: A well that is measured during specific periods or continuously monitored by automatic recorders. These wells allow a lower density of representative monitoring to occur in the years between "sweeps".

Industrial demand: Water used by an industrial facility, such as a golf-course, dairy, feedlot, power plant, mine or paper mill, and that is served by the industrial facility's well.

Inflow: All water that enters a hydrologic system. Examples include mountain front and stream channel recharge, artificial and incidental recharge and baseflow and underflow into a system.

In-lieu water: Water that is delivered to a groundwater savings facility in an AMA or INA and that is used at the facility by the recipient on a gallon for gallon substitute basis for groundwater that otherwise would have been pumped from within the AMA or INA.

Irrigation non-expansion area (INA): A geographic area that has been designated pursuant to A.R.S. §§ 45-431 or 45-432 as having insufficient groundwater to provide a reasonably safe supply for the irrigation of cultivated lands at the current rate of withdrawal.

Instream flow right: A non-diversionary surface water right for recreation and wildlife purposes, including fish.

Intermittent lake: A lake that normally contains water for only a portion of the year or one that is only seasonally dry.

Intermittent stream: A stream or part of a stream that flows only at certain times of the year when it receives water from springs, snowmelt, surface run-off or other sources.

Jurisdictional dam: Any artificial barrier, including appurtenant works, for the impounding or diversion of water, 25 feet or more in height or with storage capacity more than 50 acre-feet, except:
(a) Any barrier that is or will be less than six feet in height, regardless of storage capacity;
(b) Any barrier that has or will have a storage capacity of fifteen acre-feet or less, regardless of height;
(c) Any barrier for the purpose of controlling liquid-borne material;
(d) Any barrier that is a release-contained barrier; or
(e) Any barrier that is owned, controlled, operated, maintained or managed by the United States government or its agents or instrumentalities if a safety program that is at least as stringent as the state safety program applies and is enforced against the agent or instrumentality.

Maximum storage capacity: Total storage space in a reservoir below the maximum attainable water surface elevation, including any surcharge storage.

Meridian: A surveyed line that serves as a reference to which surveys are coordinated and correlated.

Metamorphic rock: A rock that is the product of heat, pressure, and chemical activity so that some or all of its minerals are re-crystallized and may show preferred orientation.

Municipal demand: All non-agricultural uses of water supplied by a city, town, private water company, irrigation district, domestic water improvement district, water cooperative or private domestic well.

Non-exempt well: Within an AMA, a well having a pump with a maximum pumping capacity of more than 35 gallons per minute and used for non-irrigation purposes or any well used for irrigation purposes. This term is also frequently used to describe any well outside an AMA having a pump with a maximum pumping capacity greater than 35 gallons per minute.

Non-jurisdictional dam: An artificial barrier for impounding water that does not qualify as a jurisdictional dam.

Normal storage capacity: the total volume, in acre-feet, at the normal retention level, including dead and inactive storage and excluding flood control and surcharge storage.

Outflow: All water that leaves a hydrologic system. Examples include cultural water demand, phreatophyte use and underflow and baseflow out of the system.

Pan evaporation: Evaporation in inches from a standard Weather Bureau Class A pan.

Peak flow gage: A mechanical device that measures the maximum instantaneous discharge of a stream or river at a given location. Peak flow usually occurs at the time of maximum stage.

Perennial stream: A stream or part of a stream with surface flow throughout the year, drying only during periods of drought.

Period of record: The length of time represented in the data.

Phreatophyte: A deep-rooted plant that obtains it water from a permanent groundwater supply.

Primary treatment: The first stage in wastewater treatment where some solids and organic material are removed by screening and sedimentation. It removes about 35% of the biochemical oxygen demand (BOD) and less than half of the metals or toxic organic substances.

Range: In the U.S. Public Land Survey System, any series of contiguous townships aligned north and south and numbered consecutively east to west from a prime meridian to which it is parallel.

Recent stream alluvium: Unconsolidated clay, sand, silt or gravel that has been recently deposited, from a geological perspective, by a stream or running water along the stream channel, on its flood plain or at the base of a mountain slope.

Reference crop evapotranspiration (Eto): An estimate of the water used by a well-watered, full-cover grass surface, 8-11.5 cm in height (the reference crop).

Reservoir: An artificially created lake where water is collected and stored for future use.

Return Flow: The amount of water that reaches a groundwater or surface water source after release from the point of use and thus becomes available for further use. In other words, that part of a diverted flow, which is not consumptively used and returns to its original source or another body of water.

Run-off: The portion of precipitation that is not intercepted by vegetation, absorbed by land surfaces or evaporated and that flows overland into a depression, lake, stream or ocean.

Secondary treatment: The second stage in wastewater treatment that involves both chemical and biological processes. The screened wastewater is passed through a series of holding and aeration tanks and ponds further removing organic and inorganic substances. Disinfecting with chlorine may be included.

Secondary treatment with nutrient removal: An additional process in the secondary treatment of wastewater that removes nutrients such as nitrogen and phosphorus.

Section: In the US Public Land Survey System, one of the 36 subdivisions of a township. A section represents 1 square mile or 640 acres.

Sedimentary rock: A rock formed by the accumulation and consolidation of loose sediments in layered deposits.

Snowcourse: A permanent site where measurements of snow depth and snow water equivalent are taken at multiple locations by trained observers. A Snowcourse is generally 1,000 feet long and located in small meadows protected from the wind.

Snow water equivalent (SWE): The amount of water contained in the snowpack that would theoretically appear if the snow were melted all at once; also known as snow water content.

Spring: A place where water emerges naturally from the earth without artificial assistance onto the land surface or into a body of surface water.

Stockpond: An impoundment of any size that stores appropriable water and that is for the sole purpose of watering livestock and wildlife.

Superfund: The federal government's program to clean up the nation's uncontrolled hazardous waste sites, also known as "CERCLA," the Comprehensive Environmental Response, Compensation and Liability Act of 1980, 42 U.S.C. §§ 9601, *et seq.*

Surface water: An open body of water such as a stream, lake, or reservoir.

Surface water standards: Numeric and narrative criteria developed to ensure surface water quality for 6 designated uses; aquatic and wildlife, body contact, fish consumption, domestic water source, and agricultural use for irrigation or livestock watering.

Tertiary treatment: Wastewater treatment beyond the secondary or biological stage that includes the removal of nitrogen and phosphorus and a high percent of suspended solids through chemical and mechanical means such as additional filtration, carbon adsorption, distillation and reverse osmosis.

Township: A unit of survey in the U.S. Public Land Survey System that represents a piece of land that is bounded on the east and west sides by meridians approximately 6 miles apart.

Underflow: The downstream flow of water through permeable deposits underlying a stream.

Volcanic rock: A finely crystalline or glassy igneous rock resulting from volcanic action at or near the earth's surface.

Water Adequacy Program: The program implementing A.R.S. § 45-108, requiring a developer of subdivided land outside an AMA to obtain a determination from the Department regarding the availability of water supplies before the land may be marketed for sale or lease to the public, unless the land will be served by a water provider designated as having an adequate water supply. Under this regulatory program, developers are required to disclose a determination that the water supply is inadequate to potential buyers.

Water duty: The amount of water that is reasonable to apply to irrigated land to produce a crop. The water duty accounts for field location and soil type, and incorporates consumptive use, evaporation and seepage from the farm water delivery system and the water that is returned to the soil via percolation and runoff.

Water year: A 12-month period beginning on October 1 and ending on September 30. The water year is designated by the calendar year in which it ends, e.g. the 2006 water year ends September 30, 2006.

Well yield: The volume of water discharged from a well in gallons per minute or cubic meters per day.